To what extent is creativity embedded in Scottish Secondary school science teaching and learning?

An analysis of secondary school science teachers' perception on creative teaching and learning under Curriculum for Excellence guidance

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Declaration of authenticity and author's rights

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination, which has led to the award of a degree.

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Abstract

Creativity is commonly acknowledged to be a value and its implementation has proved to be beneficial in a variety of fields such as social science, economics, arts, and personal wellbeing. In the last century, scholars have been debating the characteristics of creativity while trying to define tools capable of enhancing it. This study aims to contribute to such a debate by exploring the idea of creativity and creative teaching in the context of the Scottish education system, which is ruled by the Curriculum for Excellence (CfE). Namely, CfE has its roots in the constructivist theory, which is commonly recognised to support a creative environment in schools, hence my interest in evaluating its role in promoting creativity among both teachers and students.

The data gathering of this study involved the interviews of 21 secondary school teachers (Biology, Chemistry and Physics) spanning different geographical locations in Scotland, years of teaching experience, and the affluence of their school area. I used semi-structured interviews together with an analysis based on the Interpretative Phenomenological Analysis (IPA) approach to investigate their idea of creativity in schools. This was only possible after elaborating a working definition of creativity which was the result of a deep literature review on the topic. Such definition is based on four main characteristics that are novelty, originality, usefulness, and meaningfulness. My analysis showed that more than half of the interviewees (57.1%) recognised all these characteristics of creativity, whereas a large majority (85.7%) acknowledged its usefulness and meaningfulness. Drawing upon this exploration, I developed a definition of creative lesson, based on the key concepts of novelty and engagement, that was submitted to the evaluation of teachers, academics and peers who generally provided positive feedback.

The role of CfE in promoting creativity in schools was considered limited by the interviewees and definitely limited to the Broad General Education (BGE) phase (lower secondary school) as compared to the Senior one when teachers experience a performativity effect. In fact, during the last three years of secondary school, teachers feel the pressure to prepare their students to sit for the National assessments and

perceive a lack of time which prevents them from exploring and extending creative teaching approaches. In this regard, in-depth knowledge of the curriculum proved to have a positive impact as it allows teachers to improve their time management. Despite these difficulties, several of the interviewees claimed to make an effort in delivering a creative lesson by exploiting the resources the schools and departments provide them, differentiating the assessing methods, and understanding their pupils' interests and social background.

The analysis of the interviews together with the study of the most recent literature, allowed me to design a model that describes the main contributing factors of both "creative teaching", that is the ability to deliver a creative lesson, and teaching for creativity that is the tools and actions necessary to enhance students' creativity. In this model, creative teaching relies on the curriculum's flexibility, resources, active learning, and student's knowledge. Whereas teaching for creativity (a fundamental requirement of CfE) is the result of an expression of creativity and depends on both teachers' and students' self-confidence, and therefore on the support they receive from schools, departments, family and society in general. While my investigation mainly focuses on science teaching, its conclusions might apply to a wider range of disciplines, which represents a possible future development of this study.

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A PhD is a challenging experience which requires hard work, resolution and peace of mind. During mine, I had to face some of the most difficult times of my life and, for this reason, I am even more grateful to the people who supported me all along the way.
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Author Presentations

'Building up an original framework of creativity: a socio-historical analysis' - Dr M. Egizia De Pascale, Dr Jane Essex, Dr Saima Salehjee. Poster presented at the 1st Strathclyde Doctoral School Multidisciplinary Symposium, June 2019, University of Strathclyde, Glasgow.

'Looking at science as a creative discipline. Where is Scotland in the teaching and learning of science?' - Dr M. Egizia De Pascale, Dr Jane Essex, Dr Saima Salehjee. Poster presented at the 2nd Strathclyde Doctoral School Multidisciplinary Symposium (online), May 2020, University of Strathclyde, Glasgow.

'Looking at science as a creative discipline. Where is Scotland in the teaching and learning of science?' - Dr M. Egizia De Pascale, Dr Jane Essex, Dr Saima Salehjee. Poster and oral presentation at the School of Education Doctorate Showcase (online), August 2020, University of Strathclyde, Glasgow.

'Is science a creative discipline? A study of the extent to which creativity is evident in the teaching of science in Scotland' - Dr M. Egizia De Pascale, Dr Jane Essex, Dr Saima Salehjee. Oral presentation at the 3rd Strathclyde Doctoral School Multidisciplinary Symposium (online), June 2021, University of Strathclyde, Glasgow.

'Is science a creative discipline? A study of the extent to which creativity is evident in the teaching of science in Scotland' - Dr M. Egizia De Pascale, Dr Jane Essex, Dr Saima Salehjee. Oral presentation at the School of Education Doctorate Showcase (online), August 2021, University of Strathclyde, Glasgow.

'How performativity deprives students of a full range of learning opportunities' Dr M. Egizia De Pascale. Oral presentation (online). Re/framing Educational Equity Conference (online), August/ September 2021

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Abbreviations

ASN = Additional Support Need(s)

BGE = Broad General Education

CfE = Curriculum for Excellence

DCMS = Department for Digital, Culture, Media and Sport

DRG = Doctoral Researchers Group

DSMS = Doctoral School Multidisciplinary Symposium

ERA = Emotion-Regulation Ability

FE = Further Education

IPA = Interpretative Phenomenological Analysis

NaCCCE = National Advisory Committee on Creative and Cultural Education

NESTA = National Endowment for Science Technology and the Arts

OECD = Organisation for Economic Cooperation and Development

PGDE = Professional Graduate Diploma in Education

PPE = Personal Protective Equipment

SIMD = Scottish Index of Multiple Deprivation

SQA = Scottish Qualification Authority

SSERC = Scottish Schools Education Research Centre

Chapter 1 - Introduction

This thesis deals with the role of creativity in education, with a particular focus on the teaching of scientific disciplines within Scottish secondary schools. The concepts, ideas and hypotheses reported hereafter are the result of an extensive literature review and the analysis of semi-structured interviews with science teachers working in several parts of Scotland featuring different social environments. This research aims to understand how we can define creativity in education and if teachers believe creativity is a value that needs to be added when delivering their lessons. Moreover, as this study has been developed in Scotland, it is meant to understand to what extent the Scottish curriculum, *i.e.* the Curriculum for Excellence (CfE), supports creativity in schools and which major contributing factors make a teacher or a student creative. This study adds new elements to understand how creativity influences societies, as creativity itself plays a controversial role. Undeniably, many people around the world deeply care about creativity and consider it a major value in our society. However, probably few of them would agree on a common and clear definition of it. This is not surprising if we consider that the concept of creativity spread among the masses only in the last few centuries. Indeed, the word *creativity* did not exist before 1830 and was not widely used until about 1950. The expression *'creative problem-solving'* became commonly used thanks to J. P. Guilford (Guilford, 1950) and his co-workers, who started to study its presence in school education reporting that creativity filled an important role even in leadership. The University of California's Institute of Personality Assessment and Research funded in 1949 recognised creativity as an important element of *'healthy personalities'*. The number of educational institutions interested in studying creativity multiplied during that time. The State University of New York introduced the new annual Creative Problem-Solving Institutes; S. J. Parners and co-workers founded the Creative Education Foundation in Buffalo (USA). In 1966, the Eranos Center in Switzerland hosted an international and interdisciplinary conference on Creation and Formation; in 1977, Purdue University organized Creativity Training Programs for school. This trend has continued up to our days and now being creative is considered a major advantage in many disciplines, as demonstrated by the amount of published literature on the topic. Today, everyone wants to be creative as this capability is highly appreciated in so many fields. In this regard, society complies with such a trend, and it is easy to find courses in creative writing, creative cooking, or creative management.

Given that creativity is kept in so high consideration, one would expect it to play a major role in schools' curricula and that societies would reward it, at least to some extent. This is where the creativity controversy proves to be more evident. First, most laypeople still consider creativity in schools to be a prerogative of specific subjects such as music or drama. Admittedly, at the beginning of my journey as a PhD student, I was excited to study the common ground of science and creativity because I am a secondary school science teacher and I have an interest in literature and arts, thus I was interested to know to what extent creativity intrinsic in latter could influence the former. In the last years, I realized that my perspective was biased by the most widespread idea of creativity as I used to associate creativity with the most artistic topics taught in schools. The incorrectness of this idea is inherent in the word *creativity* itself, as it derives from the word *'create'*, where being creative ultimately means to *'bring something new into the world'*, which is a process that goes beyond disciplines. Moreover, the rigid association between creativity and arts has a tremendous impact on how every education system deals with creativity. Indeed, if we would assume that only artists benefit from being creative, there would be no reason to dedicate any effort to creatively teaching scientific subjects. Therefore, given that both companies and universities actively look for creative scientists, this trend would result in a lack of skills for future generations of professionals.

Raising appreciation for creativity among the masses is also hindered by the awareness that societies poorly reward it, which is another element of controversy. This is evident in many fields ranging from scientific research, and economics, as well as art itself (!). Academics write grant proposals with the hope of obtaining funding to develop their research but in doing so, they are perfectly aware that they will be more likely to be successful if their proposal is related to something with clear practical implications and economical/political value such as the formulation of new treatments or the development of electrical engines with reduced power consumption. This kind of study will receive more appreciation when compared to novel approaches that no one has ever tested before or based on creative techniques but with lower chances of success. Consequently, the idea of *'pure science'* is rarely supported by society or even labelled as nerdish or eccentric (if not foolish).

The business world is not more sensitive toward creativity than the academic one. The market is fast, the competition is ruthless, and creative enterprises must be abandoned even before their potential can be developed. This trend is somehow surprising if we consider that each year several corporates publish their annual reports and perform public keynotes that focus on the idea of innovation and creative problem-solving. This is probably even more true for high-tech companies such as those involved in social networks, gaming, and computers (*i. e. 'Think different'* has been the slogan of a well-known computer company in the last years).

According to a study carried out in the USA, even professionals working in the archetypically creative fields of the arts believe that creativity is not a rewarding value. Artists most often struggle to survive economically unless they '*"prostitute" themselves to "uncreative" forms of employments'* (Weiner, 2000a, p. 2).

During my PhD, I studied the degree to which creativity is considered a value in Education and if it is underrated as compared to other skills or outcomes as described above. My main aim was to investigate whether teaching creativity or teaching with creativity is rewarded by society and supported by the current curriculum in Scotland and to understand the role of the school system in shaping, in turn, the perspective of creativity in future generations. However, before investigating the role of creativity in schools, we need to speculate what creativity means when related to Education. As reported in the following chapters, many scientific writings agree on a dominant view of creativity featuring some salient characteristics that apply to all fields or disciplines such as (a) it can be expressed in virtually any domain of human activity, (b) it involved the generation of something new, (c) it is not an innate quality but rather it can be achieved by anyone, (d) it is a value, (e) it is a feature of open-minded, flexible individuals who will take risks and (f) it is promoted by freedom, democracy and tolerance (Weiner, 2000a, p. 9). However, the role of creativity has been studied in many fields spanning from literature to computer software, going through technology, science, games for children, psychology, anthropology, and workplace well-being. For this reason, what we know about creativity is often the result of studies carried out in several specific fields, each with its peculiarities. With my study, I intended to shed light on the peculiarities of creativity in science education, while being aware that differences in social contexts, cultural environments, and curricula regulating the school systems, all contribute to the observed traits. Even within the same social/cultural environment and under the same guidelines dictated by the curriculum in force, different topics may be treated differently when dealing with creativity. Being creative can be considered a form of self-expression when we think of the arts, whereas it can relate to creative problem-solving when referring to business or sciences. Several authors discussed this dichotomy as the contrast between pure versus applied creativity (Scott, 1995) or *expressive* versus *productive* creativity. Even motivation for creativity can be different when comparing artistic and scientific subjects. Artists may search for novelty for its own sake, scientists may use creativity to overcome practical problems, and for both these groups creativity can be stimulated by personal satisfaction or eventually the hope of financial gain. My previous experience as an academic research scientist followed by that as a science teacher triggered my interest in creativity in science teaching although, as reported in the following chapters, most of the conclusions I reached are undeniably of general application.

Defining creativity in science teaching was just the starting point of my study. I tried to investigate the factors contributing to enhancing creativity both in teachers and students. As stated above, many studies agree that creativity is something that everyone can have. However, is this perceived by teachers? Or do they believe that creativity is more likely to be the result of a predisposition, like being able to play an instrument or being able to speak fluently several languages? What are the factors that can enhance creativity? Given that the Scottish Curriculum for Excellence promotes creativity in schools, can teachers be trained to be creative? Finally, if all teachers are equally able to deliver a creative lesson, could the social context and the school wealth influence the observed outcome?

Together with the factors enhancing creativity in schools, I wanted to also investigate those that are more likely to suppress it. For example, teaching with creativity may involve practical hands-on experiments which can be organized only in schools with an appropriate amount of funds and suitable infrastructures, such as labs and equipment or musical instruments and theatres. Time is another resource that must be kept into consideration as delivering a creative lesson involves careful design and organization, activities that are expected to be carried out while fulfilling the guidelines of the Curriculum for Excellence in terms of taught topics and assessments. Supporting creativity in students is also strongly encouraged but is creativity a skill that the Scottish education system is capable of measuring or assessing?

Another aspect of creativity I decided to study is the teachers' willingness to include it in their everyday teaching activities. Even if creativity is very much appreciated by society and considered a value in general, it requires a certain amount of dedication. Moreover, teaching with creativity means delivering something new and previously unexplored. Are teachers ready to take the risk? Indeed, not just in education but possibly in all fields, professionals experience a perpetual conflict between novelty and tradition, between being anchored to the past and pushing towards the future. In this regard, the fear of the new is probably as common as the desire for it. Being stuck in the status quo can be extremely frustrating for those teachers who want to try something new, and this frustration can have an impact on their general well-being at work. On the other hand, the comfort of what is familiar and somehow repetitive during the years can also attract many.

1.1 Creativity in the work environment: NESTA's analysis

An interesting analysis of the perception and demand of creative skills in the job market is offered by NESTA (National Endowment for Science Technology and the Arts), which is a UK-based foundation aiming to *'design, test, and scale new solutions to society's biggest problems, changing millions of lives for the better'* (NESTA, 2022). Supported by the Labour Party, NESTA was funded in 1998 through a substantial contribution from the UK national lottery and supports a great number of projects, programmes, and research projects. In 2021, NESTA started a ten-year strategy, which is meant to intervene in children's inequality, public health, and a sustainable economy. NESTA pointed out the role of creativity in a report dated back in 2018 written by Eliza Easton and Jyldyz Djumalieva, respectively Head of Policy Unit and Data Science Technical Lead at NESTA, in partnership with the Creative Industries Policy and Evidence Centre (PEC) (Easton & Djumalieva, 2018). In their report, they argued that the word creativity was currently overused, as associated with whatever product from a new tea infusion to a bank account, and this tendency might lead to undervaluing the concept of creativity itself. Easton's and Djumalieva's study proceeded by analysing the frequency and the proportions of advertisements in using the word creativity in 35 million job advertisements. The use of the word creativity appeared more often in advertisements such as medical practitioners (20 times more often), management consultants and business analysts (13 times more often), or research and development managers (4 times more often) than in job adverts such as graphic designers. The importance of creativity was particularly significant in the list of 'creative occupations', such as designer, architects, artists, and software and web developers reported by the Department for Digital, Culture, Media and Sport (DCMS) (Department for Culture Media and Sport, 2021). Furthermore, an analysis of 39 transferable skills demonstrated that creativity was the sole determinant of a higher chance of growth in an occupation. Transferable skills such as project management and organisational skills are recognised to be complementary to creativity (Caves, 2000). On the other hand, for example, detail-oriented skills follow a negative trend, which is justified by the authors as depending on the chance of referring to a computer corrector instead of hiring a person to fit that role. Even basic computer skills follow a negative trend, and this phenomenon is probably due to its association with a job that can be automated. Finally, the NESTA's report demonstrated the requirement of creative skills in jobs which were not included in the DCMS list of creative occupations. The authors achieved this result by looking for occupations that *'looked similar'* (Easton & Djumalieva, 2018, p. 6) to the ones listed by DCMS and the ones which mentioned openly the word creativity. Among the latter, they found florists, print finishing and binding workers, bakers and flour confectioners, chefs, hairdressers, and barbers. On the other hand, looking for jobs recalling the creative occupations reported in the DCMS list due to similar skill requirements opened an even wider range of jobs, such as library clerks and assistants, TV video and audio engineers, sales account and business development managers.

The authors' findings (Easton & Djumalieva, 2018) highlighted a constant tendency of the job market to require creative skills in their advertisements, often associated with project management and organisational skills. The relationship between these two skills and creativity is understandable if we consider a business environment where is required to work through projects therefore in those contexts, management and organisational skills are essential. Moreover, despite the common opinion that creative skills might be required only in academic or company positions, they cover a wide range of jobs, such as bakers, chefs, hairdressers, or florists.

1.2 Purpose of the research

The purpose of this research was to explore the idea of creativity and creative lesson of secondary school science teachers in Scotland and to investigate to what extent CfE supports them in achieving the development of this soft skill in their students. This aim was pursued answering to the following research questions:

a. What do Scottish secondary school science teachers consider creativity to be in the context of teaching and learning science?

b. What are teacher perceptions of CfE's expectations around creativity across the curriculum, and how do these expectations relate to the daily classroom practices of science teachers?
c. What teaching approaches do science teachers report using to incorporate creativity into their lessons?

The answers to these research questions shaped the findings reported in **Chapter 4** and allowed the analysis which led to the affirmations and the model designed in **Chapter 5**.

These achievements were obtained through interviewing twenty-one secondary school science teachers (Biology, Chemistry, and Physics) working in various geographical locations in Scotland with different teaching experiences, as well as the economic status of their school areas. The qualitative approach used to analyse the data gathered was the Interpretative Phenomenological Analysis (IPA), and the selected tool was the semi-structured interviews. Using a semi-structured interview allowed an in-depth understanding of teachers' ideas of creativity, creative lessons and the limits related to their exploitation at school during a science lesson. My approach involved the elaboration of a practical definition of creativity, which followed to a comprehensive literature review on the topic. The definition of creativity is based on the identification of four main characteristics, which are novelty, originality, usefulness and meaningfulness. According to my analysis, more than half of the interviewees (57.1%) acknowledged all the characteristics of creativity, whereas a significant percentage (85.7%) acknowledged its usefulness and meaningfulness. The isolation of the characteristics of creativity allowed me to write a working definition of creative lesson which is centred in the key concepts of novelty and engagement and was evaluated by teachers, academics, and peers, who generally gave positive feedback.

1.3 Creativity in the curriculum and focus on the link between CfE intentions and the role they could play in meeting them.

This study takes into consideration the Curriculum for Excellence (CfE), the National curriculum of Scotland, which guide state schools' teachers and rules the current Scottish education system (Education Scotland, 2019c, 2019d; Scottish Government, 2004). CfE is structured as a broad range of reforms, advice and instructions that concern topics and related guidelines that need to be carried out (Education Scotland, 2019a, 2019b, 2019c, 2020, 2022a, 2022b, 2022c), and its aim is *'to help the children and young people gain the knowledge, skills and attributes needed for life in the 21st century, including skills for learning, life and work'*. In fact, it is designed to help students to become: *'successful learners, confident individuals, responsible citizens and effective contributors'* (Education Scotland, 2019d).

Indeed, CfE conforms to a wider worldwide tendency that is moving education towards the acquisition of skills, as opposed to the memorisation of concepts and facts (Oosterbeek et al., 2010; Pellegrino & Hilton, 2013; The World Bank, 2011). It is recognised that once the required skills have been acquired by the students, they will be able to apply them to different situations while filling their gaps in knowledge by looking for the appropriate material (Aguilar & Turmo, 2019; Charlier & De Fraine, 2008; Fadzil & Saat, 2014). CfE intentionally emphasises creativity highlighting it as a capability that needs to be enhanced in students, as well as used by teachers in the development of their programmes and assessments. Therefore, this project was designed to focus on the representation of creativity in science education (Davies et al., 2013; Davies et al., 2014; González & Deal, 2019; Jindal-Snape et al., 2013; Tran et al., 2017), and to examine how the Scottish science teachers have responded to the CfE requests in their schools.

The outcome of this study showed that the interviewees perceived the role of CfE in promoting creativity in schools limited and mainly confined to the Broad General Education (BGE) phase (lower secondary school) rather than the Senior phase. As a matter of fact, during the final three years of secondary school, teachers experience pressure to prepare students for National assessments and perceive a lack of time to explore and expand creative teaching methods. Moreover, an in-depth knowledge of the curriculum has been shown to have a beneficial effect by enabling teachers to enhance their time management skills. Despite facing these challenges, many of the interviewees expressed that they strive to deliver an innovative lesson by utilizing the resources provided by schools and departments, differentiating their assessment methods, and taking into account their students' interests and social backgrounds.

1.4 Summary of chapters

This chapter provides a summary of commonly accepted views on creativity and the role it is acquiring in our society.

Chapter 2 deals with the history of creativity and its evolution through the centuries. Creativity is recognised as a capability that can be acquired by using different processes, which are described in detail in this chapter. The processes that I chose to follow for my study and those that I decided to dismiss are also explained together with the motivation behind my preference. The study of the available literature on this topic allowed me to design a working definition of creativity that I used to interpret teachers' experiences and ideas. Based on the constructivist theory, I explored the necessary conditions for having a creative school environment and developed a definition of creative lesson which I submitted to teachers' and academics' evaluation. The end of the chapter justifies my choice to use an approach based on the interpretative phenomenological analysis (IPA) for the data gathering and analysis.

In Chapter 3, I will summarise the epistemology and ontology behind the qualitative approach I selected, the criticalities encountered in the data gathering due to the pandemic, and the guidelines followed in the sample selection. Moreover, in this chapter, I describe the attended ethics and the approach followed for the data analysis. The trustworthiness of the approach was widely illustrated in the last part of the chapter.

The data results and analysis are explored in Chapter 4 and will be shown to revolve around five main assertions, which allow us to explore teachers' ideas of creativity and creative lesson and to highlight the criticalities associated with CfE requirements. Chapter 5 reports a discussion of the five assertions described in the previous chapter, as a result of the teachers' interviews' analysis, the available literature and the proposed model on creativity. The chapter ends with an overview of a model describing the features of creativity in schools and how they can result in both creative teaching (the ability to deliver a creative lesson) and teaching for creativity (the ability to enhance students' creativity).

The conclusions found in Chapter 6 contains a summary of the study and its results, followed by a discussion of its limitations and recommendations for future work.

Chapter 2. Literature Review

2.1 Introduction

The focus of this thesis is the study of creativity and its use in secondary schools' science teaching. My investigation has been carried out in Scotland and therefore it relies on the perception of creativity and creative teaching of teachers working in the Scottish education system, which is regulated by the Curriculum for Excellence (CfE) and provides curricular guidelines to teachers of students aged between 3 to 18 years old.

In this chapter, I am going to explore the concept of creativity, specifically applied to science teaching, considering it a skill that can be enhanced through education. In order to do that, I will describe the historical *excursus* that led to the modern idea of creativity together with the theories that guided me in this study and allows me to formulate my working definition of creativity and creative lesson. Furthermore, I will explore the role of creativity in education and the philosophical root of the approach I selected for my data gathering and analysis.

2.2 Historical overview on creativity

Human beings' traces of creativity date back to prehistory and can be found in archaeological and biological remains. The expressions of creativity along history show that its understanding of creativity have changed over time, apparently shaped by the society in which they were held. Just consider the remarkable prehistorical graffiti found in the caves of Lascaux dated back to 15,000-20,000 years ago, where it is possible to observe the creative attempt to draw a life scene and admire the capability in choosing different drawing technique and preparing the colours used to realised them (**Figure 2.1**).

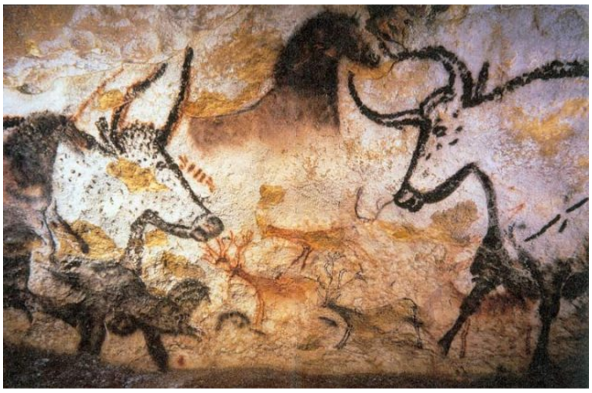

Figure 2.1. Prehistoric graffiti discovered in caves of Lascaux in 1940 (Wikipedia, 2022)

Despite all the prehistoric examples of creativity, a word defining it did not even exist in ancient Greece, China, and India. The closely related concept in ancient Greece was *poiein*, meaning 'to make' from which derives the word 'poet' (*i.e.*, maker). In fact, at that time, only poetry was considered generated by an act of creation often inspired by a deity-driven intervention (*i.e.* the Muses), whereas all the other arts were just a form of imitation of Nature. For example, the Greek philosopher Plato thought that poets' works were an invention of the Muses who possessed them,

'leaving them bereft of reason, but inspiring them to make things they otherwise could not through mere human skills' (Weiner, 2000b, p. 35)

Until the Renaissance began (in around 1300 C.E.), human expression of creativity was identified as an expression of God's will and the artist was nothing more than a vessel to be filled by His divine grace. The artists internalised so deeply these beliefs that most of them neither dare to sign their art works. Actually, later on, even Coleridge, Van Gogh, and Kipling talked about their art works as a result of an external force taking control of them during the creative process. During the Renaissance, the intellectual movement Humanism gave a new human-centric outlook of the world: the creative act was not an expression of God anymore, but an individual ability. Started around the 15th Century, the Renaissance reached its maximum splendour in Italy with artists of the calibre of Leonardo da Vinci and

Michelangelo Buonarroti and many more. In 1550, the famous painter, architect, and historian, Giorgio Vasari was the first to coin the word *Rinascita* (transl. 'rebirth') meant to express the arts renewal of that period. In his book *'Lives of Most Excellent Painters, Sculptors, and Architects'*, he described the Renaissance artists no more as craftsman but as creators of their own artistic works. Most of the artists of that period used working on commission of rich patrons who wanted to show off their power and artistic taste through the artwork they bought. However, this did not stop the artists from expressing their ideas and creativity in various forms. For example, Leonardo da Vinci filled several notebooks with his anatomic studies, which he managed to draw practising post-mortem exams on stolen human bodies.

The Renaissance time was followed by the Age of Enlightenment when the modern concept of creativity started to take its shape, together with the idea of its usefulness. The creative act became an expression of all disciplines, spanning from the scientific to the artistic ones. During the following historical period, known as Romanticism, the involvement of creativity was again shifted to the only field of arts. The creative product had to engage merely the artist's and observer's soul, and therefore any practical use was considered trivial, moreover the artist's personality was involved in the creative process. This was the time of the tormented artists such as Blake, Keats, Lord Byron, Hayez, Hugo, Foscolo, and Leopardi.

The word creativity was used for the first time in 1875 by Alfous William Ward in his book *'History of the Dramatic English Literature'*. However, at that time creativity was considered dependent only on individual intelligence, in fact, one of the most widespread philosophies was social Darwinism, which used Darwin's theory of evolution to justify social differences resulting in extreme nationalism (Lewis, 2016). It was Herbert Spencer at the end of the nineteenth century, who coined the expression *'survival of the fittest'*, inspired by Darwin's evolutionary theory and is considered the founder of social Darwinism. In this context, creativity was studied and explored only with respect to the role of people who were considered geniuses. Indeed, Spencer claimed that changes in history would not depend on those *'great men'* but were due to *'the environment, to the circumstances, the physical geography, the ancestral* *conditions, the increasing experience of outer relations'* (James, 1880, p. 2). Whereas the philosopher and psychologist William James recognized a relationship between the great men and the environment, arguing that,

'the relation of the visible environment to the great man is in the main exactly what it is to the "variation" in the Darwinian philosophy. It chiefly adopts or rejects, preserves or destroys, in short selects him. And whenever it adopts and preserves the great man, it becomes modified by his influence in an entirely original and peculiar way'. (p. 5).

Great gifted men, such as Wagner, Rembrandt, and Dickens were compared to *'ferments, initiators of movement, setters of precedent or fashion, centres of corruption, or destroyers of other persons, whose gifts, had they had free play, would have led society in another direction'* (p. 6). He considered geniuses having an influence on social evolution and settling the direction the society would have taken. They were meant to plant the seed of a plant to which everyone would have been allowed to reap the fruits. In a sort of circular vison, James thought that great men were the natural *'resultant'* of society's *'institutions, language, knowledge, manners, and its multitudinous arts and appliances'* (p. 9), and a product of the society itself.

It was a historical period in which differences were emphasised to belittle the most fragile parts of society, and it was in 1950 that creativity started to be studied thanks to Guilford's (Guilford, 1950, 1967) and Torrance's research (Torrance, 1966, 1980). J. P. Guilford developed several tests based on his theory of divergent thinking, whereas Torrance in 1966 set up the Torrance Tests of Creative Thinking that were supposed to evaluate the divergent thinking ability and the problem-solving skills using fluency, originality and elaboration capabilities as skill parameters.

Torrance's tests showed that there was no difference in terms of creative thinking skills between black and white people, arguing that *'creatively gifted disadvantaged children'* should have been supported by school and community programs respecting *'the creative positives of disadvantaged children and build upon them rather than stress compensation for deficits'* (Torrance, 1972, p. 79).

Scholars supporting the relationship between creativity and intelligence referred to the threshold theory, the certification theory, and the interference theory. According to the threshold theory (Barron, 1969; Runco, 2014), there was no connection between creativity and intelligence for IQ value over 120, and therefore, intelligence was considered necessary to be creative, but not sufficient to define it. Scholars supporting the certification theory (Hayes, 1989) argued that to be creative it was necessary to get at least a certain level of education, though they did not recognize an intrinsic relation between creativity and intelligence. Instead, the interference theory assumed that an extremely high intelligence might interfere with creativity (Sternberg, 1999). While at that time creativity was considered connected to individual intelligence, during the following years scholars argued that it was a product of imagination and resulted in the capability of generating new ideas, *e.g.* the concept of creative thinking was associated with people the society recognised as talented or even genius.

Whether a creative product was considered the result of an inspiration, or an individual capability, novelty and originality have always been the common characteristics of creativity. Through the years, creativity has been studied in terms of its connection to potential contributing factors such as education, personality, and social status. Education has always been the prerogative of affluent people who could afford to attend schools and universities, and for this reason, people who were considered creative/talented were also generally highly educated. Grammar schools funded in England and Wales and the Scottish schools funded by the reformist John Knox did not considered creativity in their curriculum, which was instead based on developing a knowledge of secular disciplines, such as Grammar, Latin, Greek, History, Natural Science, Mathematics and Religion. The first grammar schools were funded in the Middle Ages and supported by the Church; students started their studies when they turned 14 years old then attending them until starting the university or following an ecclesiastic career. During the 14th century they became independent from the church (*i.e.*, Eton College, Winchester College), highly selective and reserved to students coming from affluent families that used to live inside the schools until their entry in similarly renowned university. John Knox's Christian schools' curriculum were funded on the study of secular subjects, such as Grammar and Latin, but a particular emphasis was given to the Christian religion, as students were meant to became men who will have served the church and the state:

'For as the youth must succeed to us so we ought to be careful that they have knowledge and erudition to profit and comfort that which ought to be most dear to us, to wit, the Kirk and spouse of our Lord Jesus' (Roberts, 2009, p. 1)

Unlike the grammar schools, the schools funded by John Knox and his brethren were intended to educate students coming from affluent families as well as the ones from most disadvantaged background, whose school fees were supposed to be covered by the patrimony of the Church. However, in practice, children of less advantaged settings were not readily admitted to the schools as the Church claimed it could not cover the expenses, precluding the access to education to the most disadvantaged pupils.

The outlined historical *excursus* was characterised by a different acknowledgement of the characteristics of creativity, such as novelty, originality, usefulness. Besides the expression of creativity was always considered dependant from education and social status, in any of the period considered, whereas its reliance on personality was recognised and then explored in the last two centuries (**Table 2.1**).

Table 2.1. Characteristics of the creative act within the discussed timespan.

	Ancient Greek (800-500 BCE)	Early Christian (30-325 ACE)	Renaissance/ Humanism (1300-1600)	Enlightenment (1700)	Romanticism (1800)	Darwinism (1859- …)
Novelty	✓	✓	✓	✓	✓	✓
Originality	✓	✓	✓	✓	✓	✓
Usefulness			✓	✓		✓
Education dependent	✓	✓	✓	✓	✓	✓
Personality dependent					✓	✓
Social status dependent	✓	✓	✓	✓	✓	✓

2.3 Toward a working definition of creativity

Since the beginning of the 20th century, creativity has been studied in different fields, like psychology (Amabile & Pillemer, 2012; Gruber, 2005; Simonton, 2012), sociology (Chan, 2016; Godart et al., 2020; McIntyre et al., 2018), philosophy (Carruthers, 2002; Gaut, 2010; McQuillan, 2019), education (Sternberg, 2015; Sternberg & Kaufman, 2018; Swan, 2012), technology (Cropley & Cropley, 2009; Strandgaard Pedersen et al., 2020), economy (Dubina et al., 2021; Kiriya et al., 2020; Reader, 2006), and engineering (Daly et al., 2014; Temes, 2019; Veale & Cardoso, 2019). While philosophy, psychology, and sociology tend to study creativity in a theoretical way, disciplines such as education, engineering, and economy study the impact that it may have to enhance a person's skills, wellness or even productivity. Furthermore, the modern economy is constantly looking for new approaches to increase creativity skills, recognizing in it a potential financial gain (Dubina et al., 2021; Kiriya et al., 2020; Scottish Enterprise, 1999). For example, professor Amabile studied individual creativity from a *managerial* point of view, by looking at it as a parameter that could be enhanced to improve or even save a company (Amabile, 2017b). She argued that '*people will be most creative when they feel motivated primarily by the* *interest, satisfaction and challenge of the work itself - and not by external pressures'* (Amabile, 2017a, p. 481), as individual creativity is considered dependent on expertise, motivation, and creative thinking skills (**Figure 2.2**).

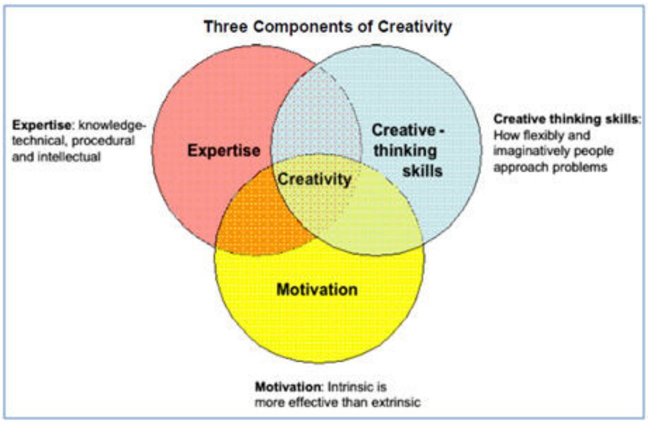

Figure 2.2. The three components of creativity at work in Amabile's theory
(Ouahman, 2016)

In Amabile's theory, expertise is the acquired knowledge (technical, procedural and intellectual), whereas creative thinking skills depend on personality, individual thinking and working approach, *i.e.* how flexibly and imaginatively people approach problems. In this regard, Amabile's viewpoint on motivation recalls Bruner's constructivist theory of extrinsic and intrinsic rewards (Bruner, 1963, 2011; Bruner & Weinreich-Haste, 1990), as motivation can be intrinsic, driven by passion and interest, and extrinsic, influenced by the work environment.

Personality, education, background, mental and neurological processes, or even mental pathologies have been analysed to understand the components of individual creativity.

An in-depth study of the literature on creativity led me to write a working definition of creativity identifying its main characteristics as novelty, originality, usefulness and meaningfulness (Feist et al., 2017b; Plucker, 2014; Runco & Jaeger, 2012). Designing a working definition of creativity was made necessary by the need to set boundaries for a capability that is often described fleetingly. Moreover, setting these boundaries offered me the chance to recognise these characteristics when analysing the words of the participants in this study. The outcome of this approach was defining creativity as the capability of generating new and original ideas that are meaningful and to a certain degree useful, where the meaningfulness and the usefulness are acknowledged by other people, or by the society (**Figure 2.3**).

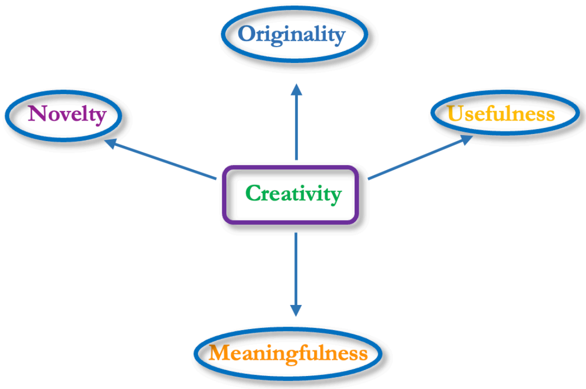

Figure 2.3. Features of creativity

This definition incorporates the concepts of novelty (new) and originality that proved to be ubiquitous throughout history as described in **Table 2.1**. Notably, while the ideas of originality and novelty are connected and, to some extent, overlap, they also differ. As a way of example, a creative writer can produce an original novel which is not necessarily new in all its part, but can be a re-elaboration of knowledge, concepts, or materials, namely a deviation of what previously was traditional or a *status quo*. However, it is not easy defining originality as scholars too had to asset boundaries to it (Feist et al., 2017c), since it is not sufficient marking something original to consider it creative, otherwise it would not be possible distinguishing a creative thought from an eccentric or a schizophrenic one. Furthermore, originality is also viewed by scholars as the result of a process obtained *'by rating an idea generated by a participant during a divergent thinking task'* (Hornberg & Reiter-Palmon, 2017, p. 276). Hence, originality cannot be defined on its own, but needs to be associated with meaningfulness, where the meaning is recognised by other people. The introduction of the concepts of usefulness and meaningfulness completes the definition of creativity and excludes eccentricity and oddness, and again, as in the case of novelty and originality, they overlap in meaning.

2.4 The creative process

Creativity does not originate from anywhere, instead is recognised by several scholars as a capability that can be enhanced since it develops according to a process. However, this process is often hindered or limited by rules or 'codes of behaviour' as argued by Koestler (1969), who claimed that it is necessary to go beyond the strict and well-defined mental structures in order to produce creative ideas. He further explained this concept when he described the way our brain works during a chess game. In fact, on the chessboard, we have a certain number of pieces that must be moved following certain rules, but we have different 'matrix', and 'codes of behaviour', that we can use to win the match. Unfortunately, our moves will be influenced by the technique we generally use, the number of matches we saw or played and our personal experiences which all contribute to creating a stringent mental scheme. However, acquiring experiences and studying new techniques also allow us to expand our knowledge which plays a primary role in the creative process. Therefore, the creative act does not originate from anywhere, rather it is a selection, recombination, a blending of *'existing facts, ideas faculties and skills'* (Koestler, 1969, p. 109). Once the concepts are well-established in our minds, we will be able to create new connections between them, while thinking at different levels. This phenomenon would also explain why some discoveries were made at the same time by different scientists, which is when sufficient knowledge is available, and new concepts can be created thanks to creative thinking. In Koestler's theory, we can recognise the concept of novelty applied to the act of creation, as the capability of generating something new for the creators themselves. This theory sanctions the bisociative thinking which is *'the various routine of associative thinking from the creative leap which connects previously unconnected frames of reference and makes us experience the reality on several planes at once'* (Koestler, 1969, p. 5).

Literature provides many models describing the creative process, and the ones selected were not necessarily the most recent, but were considered the most suitable for the type of investigation I was going to perform.

The creative processes that meet my idea of creativity are:

a) Wallas' four-stage model (Sadler-Smith, 2015; Wallas, 1926)

b) Guilford's convergent and divergent thinking theory (Guilford, 1950, 1967)

c) Fauconnier and Turner's conceptual blending theory (Fauconnier & Turner, 1998, 2008; Koestler, 1969)

d) Four-C model of creativity conceived by Kaufman and Beghetto (Kaufman & Beghetto, 2009).

2.4.1 Wallas' model of creative process

In 1926 Wallas published his work *The Art of Thought*, where he presented one of the first models describing the creative process (Wallas, 1926) which involved three stages: *preparation*, *incubation*, and *illumination*. The person involved in the creative process was aware of the problem in its wholeness during the preparation stage. This phase was conscious, voluntary, and directly connected to education as only an *educated man* could reach the necessary and sufficient number of experiences and words that enabled *him* to create new associations, different from the habitual ones. The preparation was followed by the *incubation* stage, which was a phase of unconscious thinking. Wallas argued that incubation can be the result of either a *distraction*, occurring when the mind was busy working on other problems, or a status of *mental relaxation* when the mind was not kept busy by any thought. *Distraction* was suggested to be linked to less creative thoughts, whereas *mental relaxation* was more likely to result in more creative works such as a poem, a scientific discovery, or a political decision. The creative process ended with an *illumination* stage characterised by the birth of a new creative idea. Wallas was deeply influenced by the German physician and physicist Hermann Helmholtz during the development of his framework, as shown by the analogy between the illumination stage and the concept of *happy ideas* described by Helmholtz during his 70th birthday banquet (1891), *'Happy ideas come unexpectedly without effort, like an inspiration. So far as I am concerned, they have never come to me when my mind was fatigued, or when I was at my working table …. they come particularly readily during the slow ascent of wooded hills on a sunny day'* (Wallas, 1926, p. 80).

In a later stage, Wallas added an intermediate stage to his model of a creative process called *intimation* that occurred between incubation and illumination and is described as a sort of *'fringe consciousness'*. In his revision of Wallas' work, Sadler-Smith (Sadler-Smith, 2015, p. 12) described the intimation stage as *'a rising train of association'* (p. 13)that reaches a state of consciousness running over the illumination stage and there lasting for some time.

Following the study of Poincare's writings, Wallas' theory evolved to include a fourth stage that was called *verification*, and corresponded to a phase of conscious verification, elaboration and application of the creative ideas generated during the illumination stage (**Figure 2.4**). The illumination and the verification stages were conscious, too. The former was characterised by the achievement of a *train of association*, ending up in the final *happy idea*, and the latter followed mathematical and logical rules.

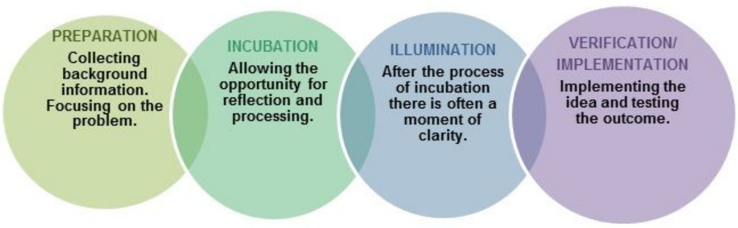

Figure 2.4. Wallas' model of creative process (RMCA, 2020)

The most fascinating thing about Wallas' theory was that he did not make any distinction between the scientists' and artists' creative processes designing a process that could describe a scientific as well as an artistic creative outcome. However, whatever was the field creativity expressed itself in, Wallas' model presupposed that the creative act was the result of in-depth knowledge of the subject under study and therefore accessible by just an *elite*. Moreover, even if the creative process was articulated in four stages (five if we consider the intimation too), it is important noticing that Wallas' theory preserved the spontaneity associated with the creative act.

2.4.2 Guilford's convergent and divergent thinking theory

The convergent and divergent thinking theory was developed by Guilford (1950, 1967) and specifically divergent thinking is considered nowadays as children's natural approach to outside world phenomena, namely a thought process characterised by new solutions arising naturally from different ideas and unexpected connections (Huo, 2020; Palmiero et al., 2016). For example, when a teacher proposes a multiple-choice problem, convergent thinking pupils will try to guess the only correct answer, whereas divergent thinking students will try to evaluate the reasons why any of the answers can be correct following a non-linear mental process. When asked to solve a problem, divergent thinkers are recognised as creative, curious and unconventional, whereas convergent ones are considered more rational, practical and, in some way, rigid (Silvia et al., 2008). Guilford argued that creativity was not a matter of intelligence but personality, and considered curious, not conformist, persistent minds more creative. He proposed to measure divergent thinking by evaluating fluency, flexibility, and originality, quantifying the number of ideas produced (fluency), the strategical ability to move from one problem to another (flexibility) and the ability to produce new ideas, different from the ones produced by most of the people (originality). In this respect, Edward de Bono's theory on lateral thinking complemented Guilford's theory on divergent and convergent thinking (De Bono, 1970, 1996), arguing that creative solutions to a problem arose by looking at it from multiple points of view.

At the time Guilford was developing his theory, creativity was still considered related to intelligence, but he demonstrated that this relationship was extremely weak in general and completely absent when considering subjects with an IQ level of more than 120. This marked the end of an era where only people with high IQ were expected to be creative, and scholars started to design questionnaires on creativity quotients, personality, and self-reports to measure creative ability (Feist, 1998; Feist et al., 2017b; Vartanian et al., 2018).

2.4.3 Fauconnier and Turner's conceptual blending theory

The pedagogical technique of conceptual blending was developed by Fauconnier and Turner who were inspired by Koestler's work on creativity (Fauconnier & Turner, 2002; Koestler, 1969; Turner & Fauconnier, 1999). Conceptual blending was based on the development of the creative thought as a dynamic process which happens in mental spaces, that are theoretical constructs where an individual builds up new meanings of the reality. The spaces existing between the concepts acquired by a person are the areas where blending these concepts could generate new ones and *'conceptual integration is at the heart of imagination. It connects input spaces, projects selectively to a blended space, and develops emergent structure through composition, completion, and elaboration in the blend'* (Fauconnier & Turner, 2002, p. 89).

A broad distance between concepts results in a larger space where they can blend and thus promote original and creative connections.

Referring to this study and applying this theory to modern teaching, it is possible to affirm that teachers could exploit spaces between unrelated topics or disciplines to engage students in the lesson and enhance their capability of creating new and original connections (*e.g.,* multidisciplinary connections). Moreover, the outcome of this approach would be students' development of a more comprehensive knowledge.

2.4.4 Kaufman and Beghetto's four - C model of creativity

At the beginning of 2000, Kaufman and Beghetto proposed the Four–C model of creativity (Helfand et al., 2017; Kaufman & Beghetto, 2009; Kaufman & Sternberg, 2010a). Until that time, creativity was divided into everyday creativity, also known as little-c creativity, and Big-C creativity which referred to genial creations that only an *elite* group could experience, with no nuances among these two classes. The introduction of two additional types of creativity, the mini-c and Pro-c creativity, allowed them to obtain a more comprehensive model (**Figure 2.5**). The mini-c creativity represented the creative effort produced during the learning process that results in generating an outcome that is not revolutionary but new and meaningful to the creator whereas, a professional level (Pro-c) represents an effortful development, *i.e.* a *'professional level of expertise in any creative area'* (Beghetto & Kaufman, 2014).

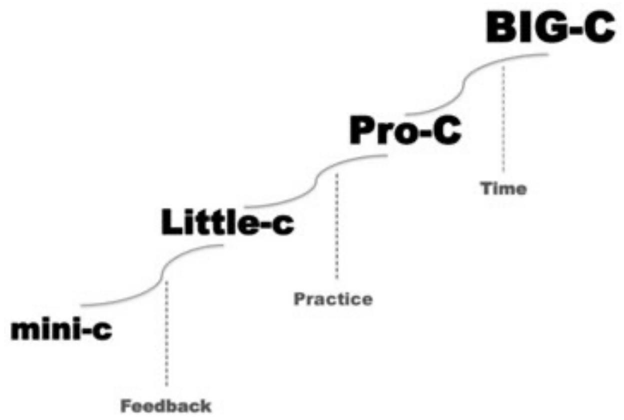

Figure 2.5. Kaufman and Beghetto four-C model of creativity (2014, p. 55)

Notably, all the described phases were connected, and people can move through them during their life. Mini-c creativity could be experienced during the building-up of personal knowledge, *i.e.,* in the school environment where the students start to recognise their creative potential and, consequently, improve their self-confidence. Little-c was achievable through a practising period of personal growth and could last all life or improve after a period of informal apprenticeship to Pro-c creativity. The informal apprenticeship, usually represented by an academic development, lasted quite often at least ten years and the researcher was driven on this path by a mentor or an older and more experienced colleague. Once reached the Pro-c level of creativity, there could be a stasis or a 'run towards the greatness' resulting in the experience of a Big-C. Among the forms of creativity described by Kaufman and Beghetto, little-c and Pro-C, relies on constant work and study, with the school and the University being their natural environment.

Basically, this theory acknowledges that creative capabilities could develop during the education process and throughout life. This meant recognizing creativity as a capability, not an inborn quality namely, a soft skill which can be developed and boosted within the classroom if supported by teachers and by a proper education system.

2.4.5 Dismissed Models

I found several analogies and connections between the creative process models I rejected and the ones I chose and that is probably due to the newest models being influenced by the previous ones. My choice of dismissing some theories on creativity was driven by having recognised that they were not suitable to provide a comprehensive study on my research topic. In the following paragraphs, I will describe the reasons why I decided not to use well-established theories and approaches such as the creative cognition approach designed by Finke, the explicit–implicit interaction hypothesised by Hélie and Sun and the honing theory proposed by Gabora.

Finke's theory of creative cognition is based on the *geneplore* model that describes the creative process as the result of a generative phase followed by an exploratory one (Finke et al., 1992, 1999). During the generative phase, a person is expected to build up some mental representations that are called pre-inventive structures and that will be used later to generate new ideas in the exploratory phase. In my opinion, Finke's description of the generative phase shows some similarities with the phases of the creative process described by Wallas. In fact, Wallas' preparation stage was a conscious phase in which the problem was analysed through the acquired knowledge, which is in line with the generative phase suggested by Finke. The acquired knowledge is then used during an unconscious stage represented by both Wallas' incubation/illumination stages and Finke's exploratory phase. Moreover, Finke argues that these mental processes could be prevented by a person's previous experiences or knowledge, which is a phenomenon earlier described by Koestler. Finke suggests that our previous knowledge and experiences lead us to follow certain 'matrix' or 'codes of behaviour', that need to be removed to develop new ones. The main innovation of Finke's theory might be considered the study of these factors to determine which ones assist or inhibit the creative act. Like his predecessors, he believed that the "normal" and the "genial" minds followed the same principles, and the 'proper creative' result was due to factors such as an 'intrinsic motivation, situational contingencies, the timeliness of an idea, the value that different cultures place on innovation, and so on'. Again, earlier scholars such as Guilford, Koestler and Wallas had already analysed these factors recognising the influence of time and society on creativity and, in my opinion, Finke focused on the process rather than on the characteristics.

Helie and Sun reported the psychological theory of explicit-implicit interaction (Hélie & Sun, 2010, 2015), which recalls Guilford's problem-solving approaches to divergent and convergent minds. Using a complex computational psychological model, they integrated the results of both implicit and explicit processes, where the implicit processes of problem-solving create hypotheses that are later *'explicitly tested'* leading gradually to the solution. Unfortunately, the explicit way does not work properly with the most complicated problems, an additional stage, also known as *'insight'* must be performed. This computational psychological model reminds Wallas' model as in psychology the implicit knowledge is considered connected to an unconscious person's behaviour, whereas the explicit knowledge is conscious. If we compare the explicit and implicit processes to Wallas' four-stage creativity model, we notice that the explicit processes can be compared to the preparation stage, the insight to the verification stage, and the implicit one to the incubation stage.

Finally, Gabora's honing theory is based on the actualisation of ideas, that from a potential state come to life through a process of honing and re-honing depending on

the social context and the worldview of the individual (Gabora et al., 2012; Gabora & Unrau, 2018). It is a circular process that recalls both the scientific method and Wallas' model which are based on a reiterative loop in which ideas are refined, verified, modified, and eventually generate new ideas.
The theories described in this section are to some extent innovative and often rely on complex mathematical models. While I certainly acknowledged and appreciated the strength of these models, I did not believe that the added complexity was necessarily beneficial for the type of study I was going to perform. Moreover, the broad overlaps between these theories and those described in **Sections 2.4.1** - **4** led me to limit the number of models.

2.5 Creativity in school context

To study creativity and creative science teaching, it is important to establish which school environment is the most appropriate to develop a creative lesson. The importance of school in creativity development has been studied in-depth in the last decades. A school environment that nurtures creativity requires the teachers to be engaged in this process and to be happy with the implications this implies. This means accepting a constructivist approach to the lesson, implementing divergent thinking in class, and recognising the mode and time of creativity. Recognising the mode of creativity requires an adequate understanding of the students to appreciate which is the limit they impose on their creative expression. (Baer & Kaufman, 2012; Banks Gregerson et al., 2013; Davies et al., 2013). A lack of self-confidence might stop pupils from expressing their creativity. For example, planning a class activity that involves presenting an essay or reading a poem in front of the class, might result in pupils avoiding the challenge due to the fear of being judged. (Safitri & Widjajanti, 2019; Sheldrake, 2016). However, teachers need also to explain to their students when it is the right time for their creative self-expression (Kaufman & Beghetto, 2013).
Assuming that creativity is a capability that can be enhanced or reduced implies that it represents an innate potential, *'an inherent part of the everyday human experience'*

(Beghetto & Kaufman, 2014, p. 53) that can be developed in an appropriate (school) environment. This statement implies that creativity should not be *'killed'* (Amabile, 1998; Robinson, 2006), can be shown in different contexts (Amabile, 1996; Baer & Kaufman, 2012), and sometimes is not easy to be recognised (Cropley et al., 2019; Karwowski et al., 2020; Kaufman et al., 2013), but needs always a proper environment on which to flourish (Baer, 2016; Baer & Kaufman, 2012). The school plays a primary role in all these aspects of creativity. Teachers can indeed nourish (or inhibit) pupils' creativity, can recognise their creative expressions in different contexts, and can create an environment where these expressions can take place more easily. This power (and responsibility) is in the hands of all the teachers regardless of the subject they teach since nowadays creativity plays a primary role in all disciplines (contrary to what was previously believed when creativity was only considered linked to arts and literature).

The school does not only represent the environment where the students can enhance and express their creativity but also where teachers can do the same (Hong et al., 2009; Soh, 2017). In fact, one may argue that delivering a creative lesson may be a way to stimulate creativity in pupils. However, a major issue in defining what makes a lesson creative is recognizing which approach would prove to be more effective in enhancing students' creativity. In this regard, two main teaching approaches exist (often shading into each other) hereafter referred to as conventional and non-conventional. A conventional lesson is often based on the use of textbooks, which drives the pupils through the study of the subject in terms of order and difficulty. The teacher supports the students during this process by answering questions and providing further explanations, if necessary, but does not adapt the subject to the students' capability and skills. This results in a lack of freedom in the way the teaching is delivered and ultimately proves to be unsatisfactory for both students and teachers. On the other hand, a non-conventional approach results in a lesson that is centred on students, and on their skills and potential. A teacher that wants to develop a lesson in a non-conventional way will consider the background of the students and the social context. Moreover, a non-conventional lesson will be built considering semantic variations and examples recognizable by the students because part of their world. As a result, the students will not consider the subject under study as something abstract, but real and tangible. A non-conventional lesson might include practical experiences where the students are involved in activities that will allow them to link the studied concepts to their everyday life. In fact, it is well-known that in a science lesson, the learning by doing approach with laboratory experiments helps the retention of the concepts, especially if students can perform the activities on their own, and are not just as mere observers (Drake et al., 1984; Dwikoranto et al., 2020; Russell & Weaver, 2011). In conclusion, the main difference between a conventional and a non-conventional lesson is their focus. A conventional lesson revolves around the textbook, and no attention is paid to students' skills, freedom of teaching, or social and school environment. On the other hand, a non-conventional lesson is centred on the student, the individual learning process, and the individual teaching approach . By encouraging the latter approach, the school recognises the importance of the students' and teachers' wellness, can enhance students' creative skills, and boost a creative teaching approach (Banks Gregerson et al., 2013; Beghetto, 206; Beghetto & Kaufman, 2014).

2.5.1 A constructivist approach: the roots of constructivism

The strong link between a supportive educational environment and creative skills is quite clear once we relate it to the constructivist approach. A constructivist environment in school, by which we mean an environment in which learners are seen as actively creating their own meaning, rather than being passive recipients of knowledge, can help to enhance students' creativity, as it stimulates self-confidence and freedom of expression, empowering students' skills (Bodner, 1986; Krueger et al., 2005; Sjøberg, 2010).

In 1943, Gallagher, referring to literature and history, wrote about the uselessness of teaching students a subject through repetition and memorization (Gallagher, 1943) and he articulated his thought starting from the question *'What of it?'*. He argued that if this question crosses the students' minds during a lesson or an assignment, it means that the teacher failed in stimulating students' learning. It meant that the teacher might have been able to make the student understand the topic, but not learn it. Learning is not just merely understanding but involves the ability of interpreting, thorough evaluation and criticism, understanding the deep significance, and creating associations. Gallagher argued that real learning was composed of *'judgements, opinions, and conclusions'* and even when facing students' lack of interest in certain topics or disciplines, the teachers should appeal to their *'motivating power'* to stimulate students' interest. He recognised the combination of interest and purpose as the driving force in students' learning process. Gallagher's innovative thought fits perfectly this study as it introduces the importance of engaging students in the lesson to empower their learning and develop their critical thinking, which will be explored in-depth in the following chapters.

Gallagher's thought was ground-breaking as at that time, the most diffused education philosophies were teacher-centred, and students were considered as vessels to be filled by the absolute knowledge belonging to teachers. It was the time of essentialism and perennialism, which are education philosophies that have never been really completely abandoned and are currently in use in some schools (Dewilde & Skrefsrud, 2021; Linsbichler, 2017; Stern et al., 2020). Following those philosophies meant assigning a passive learning role to the students, the selection and predominance of some disciplines over others (*i.e.* maths, science, or literature), the religious influence on some studies, and the compulsory choice of the so-called *'great books'*.

Dewey, Vygotsky, Piaget, and Bruner are considered the first scholars who started to consider children's development and education in a constructivist way and their thought shifted the focus of governments, society and teachers to students. Dewey considered children as active members of the society, who needed to be educated for the role they wanted to play, by considering their skills, capabilities, and interests (Bruner, 1971; Dewey, 1897, 1910; Johnson et al., 2017). Education was regarded as an expression of democracy that everyone must be able to access. In this scenario, schools had to be set in the society the children lived in and be considered as the means to quench the students' thirst for knowledge rather than an imposition, with the successful integration into the society being the only conceivable assessment.

While school represents the main environment where the education process takes place, a primary role is played by the social context in which the students develop. The Soviet psychologist Lev Vygotsky is known for his theory on children's cognitive development which relies on the idea of sequential phases during the learning process, each of which is considered crucial as it enables the access to the following one (Vygotsky, 1978, 2012). Vygotsky's major contribution to the constructivist approach was his idea that the social context the children are living in and the interactions they have with such environment are both major contributing factors in the children's cognitive development.

Piaget's also theorized that learning is a process that can be divided into phases, depending on brain development and strictly connected to age, but also argued that children thinking is qualitatively different in each stage, and all children go through the same phases in the same order but not necessarily at the same rate (Inhelder & Piaget, 2013; Piaget, 1964, 2013). Piaget's reviewers claimed that his point of view was based on too small samples, as he mainly studied the growth and learning process of his three children.

Vygotsky recognised the importance of teachers and parents in children development, whereas Piaget emphasised the importance of the brain development. Piaget viewed the children as solitary learners, who learn from the interaction with the environment without the support or help of parents or teachers. On the contrary, Vygotsky believed that children development of knowledge could be possible only through socialization, and especially with more knowledgeable adults, such as teachers. Another important difference between Piaget and Vygotsky concerned their idea on the language development. In fact, Piaget argued that the language was a tool which children could develop only accordingly to the achievement of certain milestones, whereas Vygotsky looked at it not just as a tool, but as a product of social communication too, essential in the thought process. Vygotsky proposed the theory on children learning based on zones of proximal development, where he argued that learning occurs when children tasks are settled slightly beyond their competence but achievable through teachers' or parents' guidance. He looked at children as people whose cognitive development was not dependant on their age, as proposed by Piaget, and occurred at different rates. In some way, Vygotsky was an *ante litteram* supporter of a differentiated approach to education depending on children' skills, and of their engagement in the learning process. In fact, proposing to children tasks just slightly beyond their competence was meant to stimulate their curiosity, critical thinking and problem solving and eventually boost their creativity.

Bruner, who is considered the founder of modern constructivism, was strongly influenced by Dewey's, Vygotsky's, and Piaget's ideas (Bruner, 1971, 1990, 2011). He considered learning as an active process, where the students can use their previous knowledge to build up new concepts and ideas. Students learn through exploring and manipulating objects, being involved in productive conversations with their classmates through questions and disagreements and doing experiments. This approach is based on Bruner's agreeable belief that the easier concepts to be remembered are those that the students discover by themselves. His constructivist theory was based on the following four principles:

- Students should approach the learning activity with a positive attitude, which implies there must be an initial predisposition/predilection.
- Teachers must recognise their pupil predisposition/predilection and organize their lessons accordingly.
- Teachers should adapt their teaching approaches to the different stages of the children cognitive development, which results in an experimental phase, mainly based on direct experience, followed by an iconic phase, in which images are used to stimulate the learning process and finally a symbolic phase where codes and symbols (*e.g.* language and numbers) are used to deliver the information.
- Students need to seek an intrinsic reward, that is the self-approval for the work done and the success obtained, and not for teachers' approval, which is an extrinsic reward.

Thanks to their contributions to philosophy of education, the authority figures were knocked off the pedestal, thus encouraging a more democratic environment, where learning became a process between peers. Teachers were expected to collaborate and work through projects, while students were encouraged to develop as human beings while being aware of ethical issues such as sexism, racism, and human rights. Students' skills and interests became the focus of the teaching experience. This marked the birth of the constructivist approach to education.

2.5.2 A constructivist environment at school

Constructivism in education has deep roots, and nowadays is one of the most used, studied and constantly evolving approaches. It recognises that human knowledge cannot be developed only through the transmission of concepts from teacher to student but needs to be built up through experiences (Krueger et al., 2005; Sjøberg, 2010). The constructivist teaching approach supports a peer environment, where each skill is enhanced and contributes to the development of new concepts through projects linked to real-life experiences. Hence, a constructivist environment is a classroom where lessons are no more based on the memorisation and repetition of the concepts explained. The students are invited to enhance and endorse their skills with their classmates and to learn by experiencing practical activities or games. In this scenario, teachers coordinate students' work and help them to reach the appropriate conclusions by themselves while stimulating their critical and analytical skills. Furthermore, teachers must consider students' social background, as the lessons (as well as the school) must be embedded in it. Students learn to recognise associations between what they study and their own life and become able to create new ones. In this context, teachers are mediators and facilitators that encourage students in developing their ideas, but also their critical minds. Teachers' role is undeniably complex as they have to stimulate the development of new ideas and connections while preventing the students to forget the main goal of the lesson.

In contrast to a constructivist environment, there is the didactical one, where lessons are often based on textbooks, tied to the current curriculum, and teachers drive the students through the subject according to the order and difficulty proposed by the book itself. The teacher is stressed by the imperative of respecting a timetable to get the students ready for the assessments, and this approach results in the difficulty of adapting the subject to the students' capability and skills. This teaching approach does not consider students' requirements and neither gives any possibility to teachers to be deeply involved in the subject taught. This resulting lack of freedom is unsatisfactory for both students and teachers, enhancing teachers' frustration, and leading to limited results. The differences between a constructivist and a didactic approach at school can be schematized as described in the following table (**Table 2.2**).

Table 2.2. Key differences between a constructivist and a non-constructivist class environment

	Constructivist	Didactic
1.	Student centred	Teacher centred
2.	Active learning/ No memorisation of the concepts	Passive learning/ Memorisation and repetition of the concepts
3.	Diversified learning	Standardised learning
4.	Curriculum interpretation respect to students' learning	Tied to the curriculum
5.	Less standardized	Wide uniformed
6.	Lesson incorporated in students' reality	Lesson shaped by the curriculum and the assessments
7.	Students' self-expression freedom	Students' self-expression freedom not allowed
8.	Peer education (collaboration and sharing of knowledge)	Individual learning

This table highlights the connection between a creative environment and a constructivist class environment. A constructivist environment can indeed result in enhancing students' creativity, stimulating their self-confidence, giving them freedom of expression, empowering their skills, and improving their capability of creating connections.

2.6 Science in science education

2.6.1 Historical background on science introduction in schools

Science was introduced in schools in the UK in the middle of the 19th century, and in 1855, reporting to the British Association for the Advancement of Science meeting in Glasgow, the Duke of Argyll declared that science education should be based on *scientific methods* and the *history of science* (BAAS, 1856). His speech was the consequence of a spreading interest in natural philosophy (Herschel, 1831; Whewell, 1931), which applied the philosophical though to the study of nature. Natural philosophy was generally associated with physics and proceeded through the observation of a phenomenon followed by a philosophical consideration. At that time, studying the history of science was supposed to allow students to access the scientific methods. However, designing an objective science curriculum focused on the presentation of the major scientific discoveries was quite complicated as it had to compromise between politics and theological issues. Moreover, it was a common belief that if science would have been introduced in the liberal education as a mere factual knowledge, it would not have contributed to the development of the student character. This issue was considered a matter of moral, as the school curriculum was meant to forge a class of gentlemen of undisputed morality. However, this problem was by-passed through the introduction of the study of science history which offered examples of scientists of strong personality, integrity, and perseverance. Since that moment in time, science acquired a humanising role in education that crossed the centuries. The idea of school teaching and learning based on observation, memory and reasoning perfectly fitted the introduction of the scientific method in science education, which was funded on the observation of a phenomenon, followed by measurements of appropriate parameters with the purpose of drawing some conclusions.

In the first decade of 20th century, Armstrong, the famous chemist, argued that scientific research had to have an investigative approach and science had to provide an exact knowledge to be considered as such (Armstrong & Brock, 1973). His heuristic idea on the application of scientific method as a universal cognitive tool inspired several schoolteachers who looked at the laboratory training as a new way of developing the science curriculum. Meanwhile, Dewey's idea about the approach to learning in school was spreading in the USA. He criticised a knowledge based on the acquirement of facts and laws, instead promoted a scientific enquiry developed in the class through students' engagement in lessons based on everyday life experience (Dewey, 1897, 1910). Therefore, for example, Biology could be studied growing a plant, while responsible citizenship could be promoted engaging students in social and political talks where they could develop their thought and learn the use of the appropriate tools to spread it.

The approach to science education which was based on laboratory training and therefore on the scientific method, dates back to the First World War, when officers and people of the army were found lacking even of the basic scientific knowledge (Jenkins, 2013). This was thought to jeopardise the army's chance of military success and resulted in enforcing the school of thought that looked with suspicion the scientific method, in this sense Armstrong had been misunderstood as he had never claimed that science education had to be delivered exclusively via laboratory training. However, this interpretation of his thought took long to be revised by teachers especially in the UK, where school laboratory's experiments became a routine where each step was prescribed and the result guaranteed, which was not neither Armstrong's nor Dewey's idea of scientific method or scientific enquiry. Besides, the moral issue rose again after the end of the First War World, when its cause was ascribed to a lost moral purpose of science education. This issue generated new questions concerning which scientific ideas were appropriate to be transmitted to students with respect to their age. This return to an 'humanisation' of science curriculum was interrupted by the Second War World and the consequent uprising of the cold war. In that time, the army race imposed a 'dehumanisation' of the science curriculum, and school and academic education was seen as a possible resource of new scientific discoveries and qualified scientists and technicians for civil and military purposes. The new approach to science education supported by psychologists as Bruner was based on 'learning by discovery' (Bruner, 1963, 1971), and students were persuaded to believe that choosing to study a scientific discipline would have made them to a certain extent scientists too. Despite a partial success in keeping the history of science in the science education curriculum for its moral value, the school education moved to the teaching of skills and competencies, such as communicating, observing, and interpreting a process, and planning new investigations. This approach would have led to new forms of assessments based on evaluating practical skills. In the second half of 1900, the interest generated by several breakthroughs in biology, medicine, genetic engineering, environment, such as stem cell, organ transplant, and climate change resulted in the flourishing of science museums, science centres, new school and college science courses aimed to involving and including common people to develop a so-called scientific literacy (Addinell & Solomon, 1983; Cheng et al., 2008).

Nowadays, it is still difficult defining the nature of science, and in this sense philosophical, psychological and sociological studies on the development of science knowledge, science as a discipline, and science in education did not manage to properly define it (Jenkins, 2013; Wolpert, 2000). Defining science is as much difficult as providing a definition of energy, in fact the nature of energy cannot be simply defined even referring to its source or motion. Scientists have difficulties in defining science as different sciences use different methodologies, different, languages, are based on different philosophies and are differently evaluated withing the scientific communities themselves. Therefore, it is probably incorrect referring to *science* in general, instead it is better to use the word *sciences* which allows to embrace all the scientific disciplines. However, attempts were put in place to help students to understand it as well as to evaluate its understanding between students and teachers (Clough & Olson, 2007; Lederman et al., 1998; McComas, 1998).

2.6.2 Development of scientific knowledge

The meaning of the scientific method can be studied by exploring how the scientific knowledge developed according to the philosophic thought of Karl Popper and Thomas Kuhn, although this method dates back several centuries before the birth of these two philosophers. Popper believed that truth was nearly unachievable and no matter how closer to it we could get, the probability of reaching it was rare (Fuller, 2004; Nola, 1987; Popper, 2005). He thought that a modern scientific theory had to be testable, refutable, and falsifiable and that scientists must try to demonstrate its wrongness. Therefore, a scientific theory would have been valid if impossible to be falsified. Human knowledge development was supposed to be a deductive process where an upcoming problem to solve was followed by a consideration that was going to result in a contradiction, *i.e.* a conflict. Therefore, Popper's vision of science was a conflictual one, where scientists were continuously seeking to disprove their peers' claims.

On the other hand, Kuhn designed a four-phase process of scientific knowledge development (Fuller, 2004; Hedesan & Tendler, 2017; Kuhn & Hawkins, 1963) The first phase was called *pre-paradigmatic* and was considered unproductive and confusing, as different researchers' theories are competing with each one and support their own principles. This contrast results in the rise of the new paradigm, and its acceptance is followed by a sort of *routine* that corresponds to the second phase known as *normal science* where each research is developed attending the new paradigm. The advent of some anomalies correlated with the use of the paradigm causes the third phase called *crisis* that leads to its rejection and will be followed by a shift from the old paradigm to a new one, which is the fourth phase known as *scientific revolution, e.g.* the phase of the scientific knowledge development. However, a scientific revolution is always an exception and once it is over, there is a return to the normal science phase, that is the rule. Kuhn's model detractors criticise his idea of incommensurability of the paradigms, where he argued that paradigms cannot be compared. In their opinion, the paradigms' incommensurability results in a lack of objectivity, as it recognises science relativism as being the result of an agreement between scientists choosing one paradigm instead of another.

From the epistemological point of view, knowledge development can be approached through deductive or inductive reasoning. Deductive reasoning is generally defined as *formal logic*, as starting from premises that are supposed to be true, the researchers get to compelling conclusions. Therefore, deductive reasoning is not supposed to be partially valid, but it will be either valid or invalid depending on the validity of the premises. On the other hand, inductive reasoning is usually associated with *informal logic*, as it tries to build up general laws from specific cases. However, this approach leads often to probable, although uncertain laws. As expected, a deductive approach is commonly associated with quantitative research, as starting from generally recognized premises obtains a specific conclusion, whereas the qualitative one prefers an inductive approach, where the study of specific cases leads eventually to general conclusions.

2.6.2.1 Creativity in the deductive and inductive reasoning

Nowadays, creativity is considered involved in all education disciplines and more generally in all aspects of life. However, science in school is often still presented and interpreted through the scientific method, and no role is given to creativity. Deductive and inductive reasoning are not openly connected to creativity, and the literature available does not consider its role in teaching the scientific method.

The term *scientific method* was used for the first time in the nineteenth century, though Aristotle (384-322) was the first to interpret phenomena through logic, which is one of the pillars of this method. It is generally represented by 6 ordered steps that are:

a) Observation of a process.

b) Formulation of a question.

c) Generation of a hypothesis.

d) Prediction based on the hypothesis

e) Testing the prediction via a series of experiments that can confirm or disprove the hypothesis.

f) Iteration, in which the results are used to make new hypothesis and predictions.

Although the scientific method is taught to students by using such a rigorous scheme, nowadays several scientists and philosophers believe that strict linearity from the initial observation to the iteration step is not accurate. This consideration origins from their belief that scientists could move through the phases of the scientific method in a circular way (**Figure 2.6**), *i. e.* a scientific investigation can initiate from unrelated experiments or someone else's conclusion. (Feyerabend, 1987; Nola, 1999; Soler et al., 2008).

Figure 2.6. Circular representation of scientific method

Nevertheless, evaluating where creativity plays a crucial role in both deductive and inductive approaches might help in including it from the very first stages of science teaching. In order to do that, I decided to highlight the common features of deductive and inductive reasoning which are the observation, the hypothesis and the theory (**Figure 2.7**) and speculate whether creativity plays any role in them.

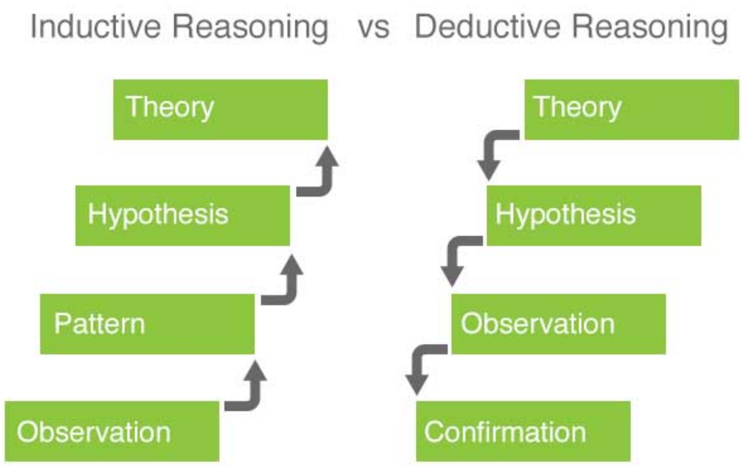

Figure 2.7. Inductive and deductive reasoning stages (Designorate, 2016)

The contribution of creativity to the observation stage is necessary to formulate new and original ideas, to both starting the inductive process and elaborating the data leading to the confirmation phase at the end of the deductive reasoning. The role of creativity in the hypothesis is hidden in its own definition; in fact, the word hypothesis comes from the Greek word *hupothesis* (ὑπόθεσις), which means 'to suppose', with the *supposition* (Carruthers, 2002; Karwowski & Soszynski, 2008) being connected to the imagination that is, in turn, recognized as a component of creativity (Bruner, 1986; De Bono, 1970; Karwowski & Soszynski, 2008). It may be concluded that creativity is involved in the theory stages of both deductive and inductive reasoning, as it contributes to the development of the theory during the analysis of the hypothesis in the inductive reasoning, and to the design of the hypothesis during the deepening of the theory in the deductive reasoning.

2.6.3 Science in science teaching and learning

In 1960, scholars started to question themselves about the place of science in education, how concepts and theory should be transmitted and the consequences of a certain science education on the society. These questions resulted in the foundation of Chem Study, the Physical Science Study Committee (PSSC), the Biology Science Curriculum Study (BSCS), Nuffield Health and Scottish Alternative, committees and institutions devoted to revise the science curriculum and its transmission in schools. The purpose was to develop a new approach to science education and resulted in dividing each science in topics such as waves, energy, or the mole, and each curriculum course to be expanded in accordance with a triplet of ideas, which for example in Chemistry was structure, bonding and energy (Johnstone, 1982). However, this triplet hided a triangle representing three level of thought (Johnstone, 1991), which can be applied to every science disciplines (**Figure 2.8**).

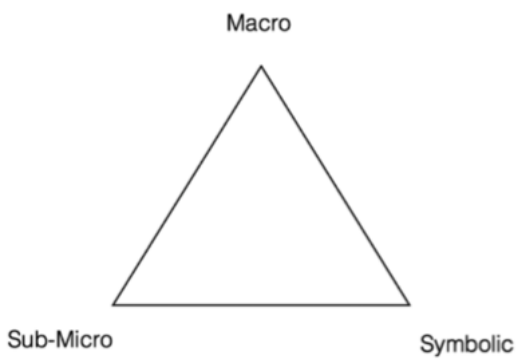

Figure2.8. Triangle representing the multilevel thought applicable to all sciences
(Johnstone, 1991, p. 78)

Through this triangle, Johnstone showed that a teacher while delivering a topic can move through all the vertices but might leave the student back at the macroscopic level. For example, a Chemistry teacher while delivering a lesson on salt dissolvement in water (macro level), might explain that this phenomenon is supported by the presence of a lattice structure of the salt (sub-micro level) and finally report it as:

$$Na^{+}Cl^{-}_{(s)} + H_2O \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)} \text{ (Symbolic level)}$$

But in all this process, it might happen that the students are still stuck at the macro level. Similarly, Physics can be divided in the same levels, the macro level might be represented by the visible phenomenon under study such as the motion, the sub-micro one by the forces and the symbolic by the math and *formulae* behind it. Whereas an example of the three levels of Biology might be the plants (macro), the cells (sub-micro) and the DNA biochemical structure (symbolic).

The issue in science transmission and students learning within the school environment remains the same and can be simplified into three reasonable causes (Johnstone, 1991). It might be a matter of the *'transmission system'*, which refers to the methods used and the facilities available, or it might be a problem with the learners, the *'receivers'*, or finally might be linked to the *'nature of the message itself'* (p. 76). However, the most plausible reason is a combination of the three of them. In his paper, Johnstone argued that analysing the problem considering only the transmission of science might led to lose sight of how students learn it. Referring to the transmission process, it is questionable if it is necessary touching the macro, the sub-micro and the symbolic levels to provide students a reasonable knowledge of science. Students learn through asking questions on topics they are interested in and in this sense, science education risk to be disconnected from pupils' reality, as more focused on transmitting theories, laws, and principles. Besides, if we consider the way science is approached on TV and newspapers, when discussing problems such as pollution, food poisoning, or even the pandemic tend to generate a sense of suspicion if not even phobia toward it in laypeople (Brown, 2012; Phillips, 2021; Rollini et al., 2022).

Laypeople's understanding of scientific concepts is based on tangible facts which are rearranged once new information or experience is added. For example, children will recognise that birds have feathers, beaks and can fly, and their little ones hatch from eggs, having seen many birds flying or their nest. However, they will rearrange their knowledge the first time they will first see an ostrich, even if is not completely covered in feathers, cannot fly, but is a great runner, and they will simply categorise ostriches as birds. Things get more complicated when teachers must explain concepts as electrons, orbitals, elements, or compounds, which cannot be seen (electrons and orbitals) or might generate confusion because most of the time appear the same (elements and compounds). A possible solution might be the laboratory practice; however, scholars have different opinions about the role of it in making science easier for students (Bradley, 1968; Hofstein & Lunetta, 1982). Johnstone (1991) argues that the main problem of using laboratory practice is the teachers' attempt to bring the experience back to the multilevel thought triangle. For example, a chemistry topic considered particularly harsh by students is the functioning of the electrolysis cell as many things happen at the same time and most of them can be described only referring to the sub-micro and the symbolic levels. In fact, students will be observing two carbon electrodes connected to a power source dipped in a blue solution of copper chloride and take for granted that electrons are moving in the solution, the brown deposit that is forming on one electrode is copper metal, and the bubbles on the other electrode are chlorine leaving the solution as a gas. It is quite ambitious showing and describing this experiment without recurring to a symbolic language made of formulas and reactions, or without talking about electrons, ions, and oxidation states (sub-micro level). Therefore, science laboratory might be a source of an even bigger issue in students leaning and the choice of a suitable laboratory experience becomes fundamental. Finally, another issue a science teacher is going to face during a science lesson is a language barrier. In fact, science often rely on words too far from students' reality which they struggle to understand and memorise (*i.e.* 'aqueous', 'discrete', or 'immiscible'). Similarly, another form of language barrier is made of the words that despite belonging to common life (*i.e.* 'volatile', 'contract') have a different meaning when referred to a scientific discipline and therefore tend to be misunderstood by students (Cassels & Johnstone, 1983, 1985).

An interesting working model proposed by Johnstone explained the issues faced by students in science learning caused by the nature of science concepts, the multilevel though, the choice of inappropriate experiments, and the language barrier (**Figure 2.9**).

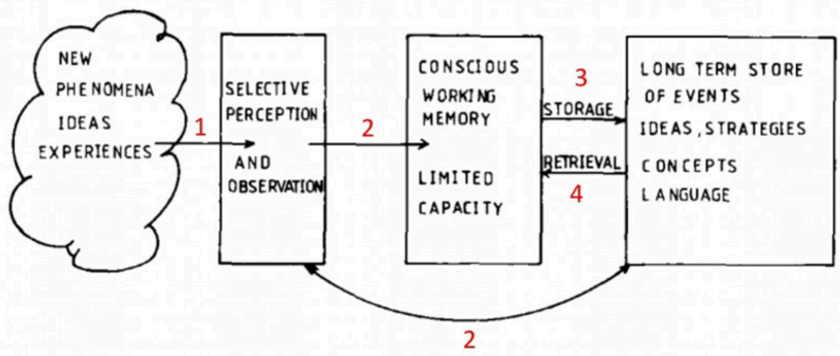

Figure 2.9. Working model of science learning (Johnstone, 1991, p. 81)

For example, many science concepts do not offer any chance of being rooted in the long-term memory of the students, possibly because they lack any correlation with what it has already been acquired. However, it might also happen that once acquired, they are presented to the working memory in a context that would not require them to solve the problem under study, indicating a misunderstanding of the proper use the science concepts. The multilevel thought instead operates on the working memory overloading it, properly because of the simultaneous use of a symbolic language associated with explanations. A way of overcoming this issue might be delivering science lessons only at the macro level offering to the students the possibility of deepening the concepts. In this way, the pupils will have the chance to decide if learning attending the three levels or not and will be assessed accordingly. The practical activities should be a compromise between a guided experiment and the students' freedom of learning. Giving excessively detailed instructions on how to perform an experiment might lead again to an overloading of the working memory, resulting in a temporary memorisation of the phases of the experiment, that will be forgotten once left the laboratory. On the other side, the access to laboratory without a sufficient prior knowledge of the theory behind the experiment might lead the students to misunderstand the meaning of the activity. Finally, we can say that the language barrier is involved in the way the science concepts are explained and in the multilevel thought due to the use of the symbolic language. In both cases, the language barrier will affect the working memory and there is no guarantee that the large number of words will be memorised in a way that allow the students to rely on them in the appropriate context.

2.6.4 Creativity in science education

In 1999 the National Advisory Committee on Creative and Cultural Education (NACCCE) published a report supporting the importance of creativity in all life aspects and its integration in all the school disciplines. In the report, it was possible to read the following recommendations for the British government and schools:

- *'Schools' development plans should make explicit reference to provision for creative and cultural education, including the pattern of provision in the formal and informal curriculum; and the opportunities for contact with outside specialists; and with the community and cultural organizations* (p. 192).
- *The DCMS* (Department of Culture, Media, and Sport) *and DfEE* (Department for Education and Employment) *should establish a mechanism and formula:*

  a. to provide all schools with dedicated funds for creative and cultural programmes and activities.

  b. to provide local education authorities with dedicated funds to co-ordinate provision for creative and cultural programmes and activities' (p. 199).

Science education can be an exceptional tool to help students in developing scientific creativity, and more generally to enhance their creative skills. A paper dated back to 2007 (Kind & Kind, 2007) reported that the use of creativity in science education was limited to an extent that did not allow to understand if students' training to scientific creativity would have made any difference in their approach to future challenges. The two scholars argued that the development of students' scientific creativity should be based on what real scientists do and should take into account *'students' needs and abilities'* (p. 3).

Before talking specifically about creativity in science, it is important to distinguish between teaching for creativity and creative teaching. Teaching for creativity means considering creativity an outcome of the teaching process, whereas when we talk about creative teaching the fundamental role is played by the teacher. NACCE defines creative teaching as, *'teachers using imaginative approaches to make learning more interesting, exciting and effective'* (p. 102). However, this definition does not give a clear explanation of what the expression '*imaginative approaches'* means but it seems to strengthen the label which would attribute a positive connotation to creative teaching being 'good' and a negative one to traditional teaching.

In their paper, Kind & Kind reported a summary checklist of 'good' creative teaching vs 'bad' creative teaching (**Figure 2.10**).

'Good' creative teaching		**'Bad' traditional teaching**	
Student-oriented	v.	Teacher-oriented	(Melar, 1993)
Group/team work	v.	Individual work	(Marazzi, 1999)
Cooperative learning	v.	Individual learning	(Anderson, 2001)
Explorative tasks	v.	Close-end tasks	(Saxon et al., 2003)
Open-ended problems	v.	Closed problems	(Schamel & Ayres, 1992)
Open investigations	v.	'Recipe' work	(Sallam & Krockover, 1982)
Hands-on teaching	v.	Lectures	(Shymansky & Penick, 1981)
Outdoor activities	v.	Classroom activities	(Boss, 2001)
Project work	v.	Lectures	(Mackin, 1996)
Issue-oriented	v.	Concept oriented	(Penick & Yager, 1993)
Teachers taking risks	v.	Teachers playing safe	(Tamblyn, 2000)

Figure 2.10. Commonly found contrasts in literature on science education between creative and traditional teaching (p. 5)

These contrasts appear slightly strict (Kind & Kind, 2007) even recognising the importance of a student-oriented lesson, group work and active learning, such as exploratory tasks, cooperative learning, and hands-on teaching, which besides have been already described as a constructivist environment supporting creative teaching (**Tab. 2.2**). In fact, it is possible to deliver a creative lesson during a classroom activity or around a certain topic. In this sense, NACCE (1999) comes to our aid defining a

creative teacher as somebody who: *'Must recognise when encouragement is needed, and confidence threatened. They must balance structured learning with opportunities for self-direction; and the management of groups with attention to individuals. They must judge the kinds of questions appropriate to different purposes and the kind of solutions it is appropriate to expect'* (p. 110).
This definition supports teachers' freedom to plan their teaching and students' learning despite of their approach.

Kind & Kind suggest approaching science teaching relying on a certain degree of self-expression, which is a characteristic of the artistic process, to give students the chance to recognise creativity in science.
Relying exclusively on an inquiry-based teaching might seem a solution to enhance students' scientific creativity and the importance of the inquiry science is not under discussion however, many scholars argue that the outcoming results of its application at school does not compensate the efforts spent (Donnelly et al., 1996; Newton, 1969; Welch et al., 1981). Still, the attempt to offer students the experience of what real scientists do often crashes with an approach to projects where each step is pre-designed, and the results expected not allowing them to observe any form of creativity.
Teaching the nature of science might be a way to demonstrate the presence of creativity, even if as shown previously it is difficult to define the nature of science itself. Besides, in this respect some scholars recognised that students understanding of it have improved there problem-solving skills (Matthews, 1994) and the *'conceptual understanding of scientific knowledge'* (Kind & Kind, 2007, p. 11; Leach, 1999). Achieving a scientific knowledge implies 'attempts' to get to it and some scholars interpret this as scientific ideas being *de facto* creative and scientists being creative people:

'Students should appreciate that science is an activity that involves creativity and imagination as much as many other human activities, and that some scientific ideas are enormous intellectual achievements. Scientists, as much as any other profession, are passionate and involved humans whose works relies on inspiration and imagination'. (Osborne et al., 2003, p. 702)

In the cited paper, Osborne argued that science teachers recognise the role of creativity in science, however some studies show that the nature of science is not deepened by classroom engagement in the nature of science (Gallagher, 1991; Schwartz & Lederman, 2002), and others that students recognise creativity just in Science in the data gathering phase (Schwartz et al., 2004).

In their paper, Kind & Kind (2007) claim that teachers who want to introduce the nature of science and scientific creativity in the classroom need to attend certain rules, such as delivering the scientific theories as creative products made by scientists, who worked together and for a long period of time to achieve those results and built them up on other scientists' ideas. Furthermore, teachers should highlight the role of imagination in the development of science, and how the process leading to a scientific theory might be *'highly creative and/or highly logic, rational and/or accidental'* (p. 14). Finally, teachers should emphasise that creativity and rationality in science move in the same direction as creativity could never lead to any result if not supported by *'rationality and strict empirical testing'* (p. 14).

2.7 Practice and policy of the Scottish education system

This study deals with the concepts of creativity and creative science teaching in Scotland and relies on the analysis of semi-structured interviews to secondary school science teachers working in various parts of the Country (**Figure 2.11**).

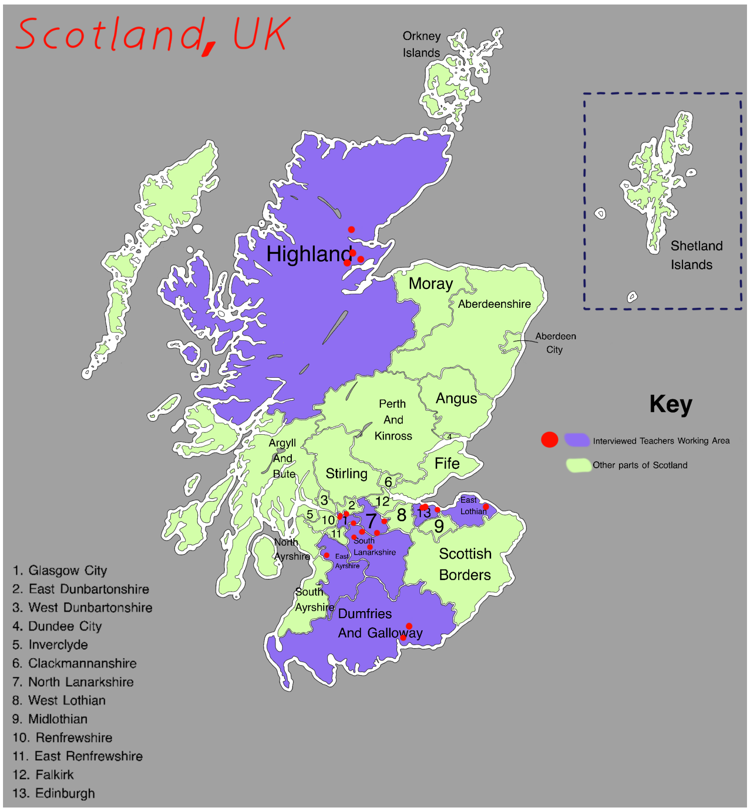

Figure 2.11. Location of interviewed teachers' schools in Scotland (Camiolo, 2022)

The Scottish education system is expected to be constructivist, as it is based on the Curriculum for Excellence (CfE), the draft of which was strongly influenced by the constructivist approach (Convery, 2017; Education Scotland, 2019d). In 2002, the 'National Debate on Education' undertaken by the-then Scottish Executive (the devolved Government of Scotland urged the development of this new curriculum as a tool to guide teachers of students aged 3 -18. CfE was reviewed by ministers in 2004 (Scottish Government, 2004) and implemented in schools in 2010 delivering a broad range of reforms, advice, and instructions concerning each teaching subject (Education Scotland, 2019c, 2020, 2022a, 2022c). CfE is intended to guide the student education from the first (P1) to the seventh (P7) grade of primary school and from the first (S1) to the sixth (S6) grade of secondary school. Additionally, the

Scottish education path is divided into a Broad General Education (BGE) phase from P1 to S3, and a Senior phase from S4 to S6. CfE is meant *'to help the children and young people gain the knowledge, skills and attributes needed for life in the 21st century, including skills for learning, life and work'* (2019d). Furthermore, its purpose and motto are to help children and young people to become *'successful learners, confident individuals, responsible citizens, and effective contributors'* (2019d), with these features being considered as individual capacities that need to be cultivated to flourish.

The BGE phase is mainly focused on students' development of *'knowledge, skills, attributes and capabilities of the four capacities of Curriculum for Excellence'* (Education Scotland, 2022a). Therefore, it is a phase where students learn according to their pace and aptitudes and the assessments are designed considering students' skills, learning time, and creativity as well. For this reason, the acquired knowledge can be assessed through a PowerPoint presentation, a video recording, a Lego building, or a standard essay depending on students' aptitudes and preferences. This phase is then meant to help students to:

- *'achieve the highest possible levels of literacy, numeracy and cognitive skills;*
- *develop skills for learning, skills for life and skills for work;*
- *develop knowledge and understanding of society, the world and Scotland's place in it, much of which is now included in Learning for Sustainability* (RCE Scotland, 2022)*;*
- *experience challenge and success so that they can develop well-informed views and the four capacities'.* (Education Scotland, 2022a)

and is considered as a preparation time for the Senior one when students can select five subjects reflecting their interests and skills. Passing the national assessments for these subjects will allow students to find a job in the fields they chose or to be admitted to colleges and universities (Education Scotland, 2022c). Four national assessments are available to students that starting with the National 4, will go through the remaining 3 (*e.g.* National 5, Higher and Advanced Higher) sorted in increasing order of difficulty. The National 4 is an internal assessment, hence written by the students' teachers, not graded however, it gives them the chance, to leave the school when they turn sixteen with a valid certificate. On the other hand, National 5, Higher, and Advanced Higher are provided by the Scottish Qualification Authority (SQA) and evaluated by external committees of teachers selected by the same authority. CfE is in line with a worldwide trend where education is focused on skills acquisition, instead of concepts memorization (Blunch, 2011; Byrne & Plekhanov, 2021; Pekkarinen & Pellicer, 2013). It supports the need to go beyond subjects' theoretical knowledge and promotes the connections between them, while focusing on developing citizenship and social science. Moreover, students' health and well-being play a primary role in CfE (Education Scotland, 2020) which can be promoted by recommending teachers and educators to build up their curriculum around students in a heuristic way while considering their life inside as well as outside the schools. Students' learning is meant to include challenge and enjoyment, progression and depth, personalization and choices, coherence and relevance, and creativity could make a valuable contribution to achieving these aims. While doing this, teachers and educators must help learners to develop confidence, independent thinking, and positive attitudes and dispositions. Hence, CfE encourages teachers and educators to develop their programmes while promoting interdisciplinarity and flexibility (Education Scotland, 2023). Interdisciplinarity is considered paramount to the development of knowledge and personal skills, and individual growth. Teachers need to collaborate with their colleagues in developing their programmes, as well as to help learners to make appropriate connections between topics, subjects, and disciplines.

Since this study deals with creativity in secondary school science teaching (although its conclusions are believed to be extendable to all subjects) it is important to notice how CfE describes science teaching with a clear constructivist approach. CfE requires the teachers to develop their lessons to achieve a more effective science learning and improve problem-solving skills and scientific-practical investigation. This is expected to be done by contextualizing lessons to student's life, using appropriate technologies, cultivating collaborative learning and independent

thinking, and designing assessments that are contributing factors to the learning purposes.
Sciences' experiences and outcomes are supposed to develop *'inquiry and investigative skills, scientific-analytical thinking skills, and develop attitudes and attributes of a scientifically literate citizen'* (Education Scotland, 2022b). The inquiry and investigative skills are supposed to develop students' ability to formulate hypotheses, plan and perform experiments after learning the techniques, but also to critically analyse the risks and the hazards, and ultimately elaborate and report the results. Students' scientific-analytical thinking skills involve the development of new ideas, *'thinking creatively and critically'*, making deductions, being able to generalize and drawing conclusions (Education Scotland, 2019a).
CfE resolutions are aligned with a constructivist view on education, where individual skills are respected and enhanced. Within CfE, creativity has had a place since its first release in 2004 and, although not explicitly defined, was recognised to be involved in the students' learning process as they are supposed to *'be active in their learning and have opportunities to develop and demonstrate their creativity'* (Scottish Government). The CfE sciences section entitled 'Experiences and Outcomes', states that students are meant to *'recognise the role of creativity and inventiveness in the development of the sciences'* (Education Scotland, 2019b). With these two statements, CfE asserts that creativity has a leading role in science's development, that students already have this capability, and that teachers are meant to help them to express and enhance it. In the previous sections, I described in detail how many scholars in the past acknowledged the primary role of the school environment on creativity development, which is a theory that the constructivist nature of CfE fully supports.

2.7.1 The fate of creativity in a climate of performativity

A constructivist approach to education supports creativity enhancement and helps to improve individual life quality and achieve personal fulfilment. Creativity is a skill that is highly appreciated by job recruiters and has a great value in the modern economy. Companies look for it within their resources and development teams, universities look for creative members to develop new projects and boost their teaching board (Easton & Djumalieva, 2018). However, when we analyse the Scottish education system, we can observe some discrepancies between what is desirable and what is requested. As previously described, the Scottish education system is divided into two phases that are the BGE phase encompassing grades from P1 to S3, and the Senior one from grade S4 to S6. During BGE, the teachers have a certain degree of freedom in terms of the way teaching is delivered and assessment types, but in the Senior phase, the pace is marked by the National assessments National 5, Higher and Advanced Higher. National assessments provided by the Scottish Qualification Authority (SQA, 2022) are based on CfE recognised curricula, and designed to assess skills and memorised knowledge. SQA National assessments are fundamental to accessing universities, which are free in Scotland, and usually require, at least five Highers. However, three Highers and two Advanced Highers in the subjects of interest of the chosen faculty are recommended to access the most prestigious university's courses. Passing the national assessments is also essential to enter the job market, as several positions require Highers marks. The impact of these requests from universities and the job market result in increasing pressure on schools, and consequently, on teachers, a phenomenon also known as performativity pressure. This impacts the way teachers deliver their lessons with the risk of affecting the development of soft skills such as creativity (Ball, 2003, 2008; Clarke, 2013; Locke, 2015).

Professor Ball defines performativity as *'a technology, a culture and a mode of regulation that employs judgements, comparison and displays as means of incentive, control attrition and change – based on rewards and sanction (both material and symbolic)'* (2003, p. 216).

Teachers experiencing performativity pressure perceive their work to be under constant judgment and tend to have an individualistic approach in their teaching while looking for productivity and striving for excellence. As a result, competitiveness increases, and teachers experience stress, anxiety and motivation loss, which is reflected in their work and their students (Ball, 2003; Clarke, 2013). Performativity effect has a strong negative influence on the features of creativity shown in **Figure 2.4**, as it is a factor of social exclusion of students coming from the most vulnerable groups and disadvantaged social backgrounds. In this context, teachers are urged to rely on more traditional teaching and assessing methods, based on delivering content and assessing memorised concepts, formulas, theories, etc. Looking at students as vessels that need to be filled with concepts and theories results in assessments that are not coherent with students' cognitive development, or sometimes even with students' language development. Students' self-esteem is affected by anxiety due to a feeling of inadequacy, or by the fear of being left behind. Hence, the performativity effect influences students' education and their chances of growing and developing as individuals, while possibly distorting their perception of their potentialities and skills .

2.7.2 Defining a creative lesson

It is a widely held opinion that teaching with creativity can result in a more effective lesson and can be a way to enhance the creativity of students as well (Banks Gregerson et al., 2013; DeHaan, 2011; Gupta & Sharma, 2019; Sternberg, 2015). Despite a general positivity towards the notion of creativity, it is not clearly defined and a consensus view on what it is does not exist. Teachers are not trained to use creativity, as in most cases, the didactic teaching approach was predominant when they were students and creativity was considered only pertinent to arts. Even defining creativity is sometimes cumbersome. Some people define creativity as *'thinking outside of the box'*. However, this definition is vague, and no one can indicate the width or describe the content of 'the box' (Glăveanu, 2014; Glăveanu & Clapp, 2018). Thinking outside of the box is often associated with a sort of eccentricity in creativity

(Carson, 2018), thus teachers are considered creative if they perform eccentrically during a lesson. Nevertheless, even in this scenario, a teacher may deliver a lesson that is not necessarily creative, as this might be of poor content and intrigue the students just because it is something they have never seen before. In this regard, teachers that misinterpret their performance as creative can as well fail to identify and handle their creative students.

While several studies have contributed to my working definition of creativity (see **Section 2.3**, **Figure 2.3**), less is known about the characteristics of a creative lesson especially related to science teaching. This lack of information could have prevented me to recognise a creative lesson within the answers given by the teachers or during the analysis of their lesson plans.

A creative lesson would probably share some of the features of creativity itself and, likewise, its definition needed to be simple, comprehensive, and generally applicable regardless of the discipline taught. The design of a working definition of creative lesson was based on literature and followed by a piloting of it as the first part of methodology and results.

A constructivist school environment supports a curriculum mainly focused on students learning and well-being (see **Section 2.5.2**), where teachers are free to design the topics under study considering students' skills and social background (Bodner, 1986; Siraj-Blatchford & MacLeod Brudenell, 1996; Sjøberg, 2010). Given the above, in this study, teachers' interpretation of CfE has been analysed in terms of its flexibility, which is a feature that is expected to be found in this curriculum given its foundations in the constructivist approach. A flexible curriculum allows teachers to respect students' learning pace and to assess them according to their capabilities. In this regard, CfE respects this constructivist requirement, but teachers' perception of their teaching freedom changes when moving from the Broad General Education (BGE) phase to the Senior one, when students are required to take the National assessments (see **Section 4.6**). During this transition, teachers perceive an increasing pressure and frustration, which results in their teaching approach becoming more didactic (see **Table 2.2**) and preferring individual rather than teamwork. Pressure and frustration are the main components of the performativity effect (see **Section 2.7.1**) and often result in teachers' lack of motivation. Teachers' frustration is due to the lack of freedom in teaching according to their style and students' skills, the feeling of not doing the best for them and the impression of being judged by the system and the society (Ball, 2003; Clarke, 2013; Locke, 2015). Furthermore, the lack of resources such as time, money and space exacerbate the situation and urges teachers to use a didactic teaching approach instead, where activities and assessments are rigidly scheduled and results immediately available. Interestingly, when asked about the adequacy of resources, the interviewed teachers seemed to perceive mainly the lack of time during the Senior phase of secondary school, though few of them also highlighted money and space lack in more deprived school areas, as discussed in detail in **Chapter 4**. The transition to a didactic teaching approach can result in a cascade of negative outcomes. Indeed, students start to lose their self-confidence, as they do not feel capable of understanding the subject and coping with the assessments and consequently the lack of results affects teachers' self-confidence in their teaching approach. All these factors affect dramatically creativity at school, as teachers in search of measurable results will not attempt any creative approach to their lesson.

2.7.2.1 A working definition of creative lesson

The analysis of the literature on the characteristics of creativity (Becker, 2011; Weiner, 2000b; Weisberg, 2015), the importance of interdisciplinarity (Sternberg & Kaufman, 2018; Thorburn, 2017) together with my considerations led to the following working definition of a creative lesson:

A lesson is creative if the teacher is able to engage the students in developing their understanding of the subject under study in a novel way, commonly by exploiting interdisciplinary connections or using topics that are meaningful to students' lived experience.

The conditions required to realise a creative lesson recall the constructivist approach to teaching as they both value active learning, meaningful engagement and developing high-order thinking while promoting practical application to real-world context (Sjøberg, 2010). However, creative teaching emphasizes teacher-led innovation with the purpose of students' learning and possibly developing creativity as a skill, acknowledging curricular constraints and overcoming them (Cropley, 2001; Swan, 2012). On the other hand, constructivism focuses on student-led knowledge construction, where the teachers are facilitators (Vygotsky, 1978). Basically, creative teaching integrates novelty and originality in teachers' lesson delivery, whereas constructivism emphasizes inquiry and peer interaction to build knowledge.

A key concept of this definition is hidden behind the word *engage*, as students' response to a creative lesson should be their engagement in the topic under study, denoting a holistic disposition of the learners. This concept is central to the definition of creative lesson as many others revolve around it. Even the expression of *'topics that are meaningful to students' lived experience'* was meant to be linked to the possibility of including students' reality in the lesson, which is a constructivist feature, that again is included in the broader concept of *'engagement'*. This word describes a mental and a 'heart' disposition of the learner, or as defined by O'Brien and Toms: *'an experience characterized by attributes of challenge, positive affect, endurability, aesthetic and sensory appeal, attention, feedback, variety/novelty, interactivity'* (2008, p. 938).

In the first draft of the definition, *'get the attention'* replaced the word '*engage*'. The former had the limit of indicating an imposition, a recall to attention, but with a disciplinary approach. Instead, the word that better evoked the responses of students to a lesson that was meant to be creative was again *engagement*, as it involves a holistic disposition of the learner. Moreover, I originally associated the expression *'get the attention'* with the word *'surprise'*, which is a concept already explored by Bruner *(2011)* and was considered a characteristic of creativity in terms of the capability to generate an effective surprise, which is unexpected and generate interest. However, generating a surprise does not necessarily result in delivering a creative lesson, but it can simply be the outcome of any unexpected event. Due to its broad and sometime decontextualized meaning, I decided to replace the word '*surprise*' with *novelty*. The word *'novel'* means 'new to the audience' as distinct from innovative, meaning 'new to everyone', it recalls the concept of novelty, which is a characteristic of creativity, and is closely related to *'original'*. As previously discussed, a novel work is not necessarily new in all of its parts but can be a re-elaboration of knowledge, a concept, or a material (Stein, 1953). The concept of interdisciplinarity is clearly expressed in the definition of creative lesson and refers to the capability of giving access to concepts and skills of a number of other disciplines while teaching a specific one. Furthermore, interdisciplinarity is a characteristic required by CfE (Education Scotland, 2019c).

In conclusion, the pillars of my definition of creativity are the keywords *'engage'*, *'novel'*, *'interdisciplinary connections'*, and *'topics that are meaningful to students' lived experience'* which represent the main concepts that have been discussed during my semi-structured interviews with teachers.

2.8 A qualitative and interpretative approach to research

When approaching a new study, researchers need to decide whether to develop it in a quantitative or a qualitative way (Castellan, 2010; Djamba & Neuman, 2002; Mahoney & Goerts, 2006). The investigation goal in quantitative research is to investigate an event under controlled conditions, measuring an outcome via well-defined parameters and confirming or denying an original hypothesis. On the other hand, qualitative research relies on understanding the meaning and describing it while making a hypothesis and eventually producing theories. The philosophical root of quantitative research is positivism, which is based on the quantification of physical and social phenomena, whereas the qualitative one roots in constructivism (Guba & Lincoln, 1998; Krueger et al., 2005; Sjøberg, 2010) and interpretivism (Kriukow, 2019; Sage, 2018; Schwartz-Shea et al., 2020), which give a higher value to subjective human experience than to objective reality. Quantitative research focuses on concrete quantities such as frequency and magnitude, while qualitative on quality or experience's meaning. Quantitative researchers collect data through tests or surveys, whereas the most important figure in qualitative research is the researcher, whose role is fundamental in analysing and interpreting the individual meaning-making of an event.

2.8.1 Validity criteria of qualitative research

A sensitive topic in qualitative research concerns its validity. Three theories on the validity of qualitative research are today widely accepted: (a) some scholars suggest applying to qualitative research those criteria that are generally used for quantitative research (Morse et al., 2002; Morse & Field, 1995); (b) some others recognise the necessity of a new specific set of criteria for qualitative research (Harrington, 1998; Sandelowski, 1986); (c) finally a third group doubts that a predetermined set of validation criteria needs to be adopted in a qualitative study (Rolfe, 2006). A strong boost to research on validity criteria in qualitative research was given by the requirement of integrating rigour, subjectivity, and creativity in the scientific process (Johnson, 1999). In 2001, Whittemore (Whittemore et al., 2001) suggested using two sets of validity criteria: primary criteria were those he recognised as essential to identifying good qualitative research; however these were sufficient, they required the use of a set of secondary criteria which were characterised by certain flexibility depending on the subject under study. This framework recognises credibility and authenticity as closely linked, as the former shows the effort in guaranteeing an accurate interpretation of data, while the latter is connected to the truthfulness of the phenomenon representation (Carboni, 1995; Maxwell, 1992). While primary criteria need to be adopted in each qualitative study, secondary ones have different degrees of importance depending on the research approach. In a phenomenological study, explicitness refers to the researcher's effort in presenting data interpretation (Sheldon et al., 1986), vividness to imagination and clarity in the presentation approach (Fenn & Geertz, 1974), and thoroughness in analysis comprehensiveness, themes connections and ideas development (Popay et al., 1998). Instead, congruence between the questions, the data analysis, the selected method, and the philosophic roots must be demonstrated during the entire research process (McGregor-Hepburn & James, 2021). The issues related to approaching research in an interpretative way lay in making assumptions and being vulnerable to bias, however, process integrity can be granted by grounding to theory and data interpretation (Johnson, 1999).

In an interesting article, Whittemore (2001) reviewed the validity criteria of qualitative research during the previous decade, with the most influential theories being reported in **Table 2.4** (marked with a superscripted *a*). Lincoln and Guba (1985) contributed to it promoting credibility and authenticity in qualitative research, whereas Marshall (1990), Smith (1990), and Maxwell (1992) emphasised integrity and criticality. Lincoln (1995) highlighted the importance of sensitivity to the participant, and Sandelowski the relevance of creativity and artfulness (Sandelowski, 1986, 2015).

Tab. 2.3. Validity Criteria development (Whittemore et al., 2001)

Author	*Validity Criteria*
Altheide and Johnson (1994)	Plausibility, relevance, credibility, importance of topic
Eisenhart and Howe (1992)	Completeness, appropriateness, comprehensiveness, credibility, significance
Leininger (1994)	Credibility, confirmability, meaning in context, recurrent patterning, saturation, transferability
Lincoln (1995)[a]	Positionality, community as arbiter, voice, critical subjectivity, reciprocity, sacredness, sharing perquisites of privilege
Lincoln and Guba [a] (1985); Guba and Lincoln[a] (1989)	Truth value, applicability, consistency, neutrality
Marshall (1990)[a]	Goodness, canons of evidence
Maxwell (1992, 1996)[a]	Descriptive validity, interpretive validity, theoretical validity, evaluative validity, generalizability
Sandelowski (1986, 1993)[a]	Credibility, fittingness, auditability, confirmability, creativity, artfulness
Smith (1990)[a]	Moral and ethical component
Thorne (1997)	Methodological integrity, representative credibility, analytic logic, interpretive authority

a. Most influential to this contemporary synthesis.

(Alheide & Johnson, 1998; Copp & Morse, 1998; Eisenhart & Howe, 1992; Guba & Lincoln, 1989; Leininger, 1994; Lincoln & Guba, 1985; Marshall, 1990; Maxwell, 1992, 2005; Sandelowski, 1993; Sheldon et al., 1986; Smith, 1990; Thorne, 1997)

I think that the criteria that better adapt to my study are *credibility*, *transferability*, *dependability*, *confirmability* and *reflexivity* which were described by Korstjens and Moser (2018), who revised the validation criteria adopted by Lincoln and Guba (1985), and

Sim and Sharp (1998). Credibility corresponds to Lincoln and Guba's truth value, and it is guaranteed by the strategy of persistent observation (**Table 2.3**). Transferability, dependability, and confirmability criteria fit the type of investigation I had planned due to the in-depth involvement in semi-structured interviews followed by a *thick description*, which is an in-depth analysis of the collected data via a step-by-step approach. This approach is used by following the order of the topics covered, developing the analysis of the data beginning with the evolution of the concept of creativity, and passing through teachers' idea of it and their application in science lessons. This process is designed considering the development and application of creativity in an education system that is driven by CfE. Finally, reflexivity plays a primary role in my study as my approach relied on the constant check of the researcher's potential bias, through self-analysis. In this regard, in order to guarantee the detection of bias and prejudices that might come from my background, I deeply discussed my approach to the study and the data analysis with field experts such as my supervisors. Finally, I decided not to use the triangulation strategy, as it does not suit the phenomenological approach, I am using due to its relativistic nature.

2.9 Conclusions

The literature research allowed me to have an in-depth understanding of creativity, follow its evolution along the timeline, and recognise its features. The acquired knowledge helped me to recognise that creativity can be described through selected models that perfectly fit the purpose of my study (Guilford, 1967; Kaufman & Beghetto, 2009; Koestler, 1969; Sadler-Smith, 2015). I consider the constructivist environment the best school environment to develop creativity and I demonstrated that the Scottish education system (McEnaney, 2021; Scottish Government, 2004) shows some discrepancies in the application of the constructivist principles. These discrepancies are mainly observed in the transition from the BGE phase to the Senior one and are eventually emphasised by the performativity effect, as will be explored in the summary of data and discussion chapters (**Chapter 4** and **5**). Defining the feature of creativity and a creative school environment helped me to write a working definition of a creative lesson which was presented in various academic contexts and submitted to the evaluation of the teachers I interviewed. This research required a qualitative approach to allow an in-depth interpretation of the data I collected during the semi-structured interviews to secondary school science teachers, and I selected IPA (Alase, 2017; Smith & Osborn, 2008a; Tuffour, 2017) to obtain their perspective on creativity and creative science teaching. Finally, I recognised as criteria validating the choice of my qualitative approach *credibility*, *transferability*, *dependability*, *confirmability* and *reflexivity* (Korstjens & Moser, 2018; Lincoln & Guba, 1985; Sim & Sharp, 1998).

Chapter 3. Methodology

3.1. Introduction

This research project originated from the current worldwide trend of considering creativity as a mean of enhancing science education (Altan & Tan, 2020; Daud et al., 2012; Dehaan, 2009). I thus planned to analyse the idea of creativity and the contribution to the adoption of creative teaching approaches by secondary school science teachers in Scotland.

Research interest in creativity and creative teaching has been growing worldwide over the last century and has been studied from the psychological, sociological and philosophical points of view (Kaufman & Sternberg, 2010b; Reader, 2006). Today, creativity is considered to be a value that needs to be enhanced in fields such as education, technology, the economy and engineering (Easton & Djumalieva, 2018).

The following research questions shaped the structure of the literature review and the title of this study:

a. What do Scottish secondary school science teachers consider creativity to be in the context of teaching and learning science?
b. What are teacher perceptions of CfE's expectations around creativity across the curriculum, and how do these expectations relate to the daily classroom practices of science teachers?
c. What teaching approaches do science teachers report using to incorporate creativity into their lesson?

This research project was developed to understand teachers' idea of creativity, and whether they engage their students in creative lessons. This outcome was reached through a qualitative approach and using semi-structured interviews as analytical tool. As the aim of this study was to explore the personal perspectives of creativity and creative science teaching by the participants, using semi-structured interviews within a qualitative approach such as interpretative phenomenological analysis (IPA) enhanced my involvement before, during and after the interviews and resulted in an increase in my sensitivity in reading between the lines, evaluating body language, and interpreting pauses. The need for an in-depth approach and the finding of a reasonable number of participants to give depth to the study inevitably required a qualitative approach. In addition, the choice of the correct approach had to go hand in hand with the idea that a soft skill such as creativity cannot be reduced to numbers.

This research was conducted at a particularly critical time, as the data gathering started, continued, and was strongly influenced by the COVID-19 pandemic. It is not possible to ignore how this global crisis has influenced teaching, which has been converted from the standard face-to-face approach in the classroom to online learning (Abumalloh et al., 2021; Daniel, 2020; Erduran, 2020). In Scotland, in March 2020 shutdown of schools drove the government to cancel Higher and Advanced Higher examinations which form the basis of university admissions in the Scottish education system.

The standard school timetable was restored on August 13th, 2020, with some changes to the normal routine with respect to precautionary measures associated with the ongoing COVID-19 pandemic. The 'new normality' imposed by COVID-19 allowed students to return to school only for the first term of the year, as lessons were again interrupted for the Christmas break and the spread of a new viral variant resulted in the school lessons being conducted online.

Considering this discontinuous period of school attendance, it is not possible to neglect the impact of this situation on a research project that was supposed to involve semi-structured interviews and lesson observations of the participants. Furthermore, due to the second COVID-19 lockdown that started during the Christmas break of 2021, the original plan of lesson observations was cancelled and substituted with the collection of some lesson plans from the teachers interviewed.

The choice of the correct methodology to be used was of utmost importance. Firstly, I had to choose between quantitative and qualitative research. Due to my scientific background, I had some preconceptions about the choice of a qualitative approach, as in my opinion a meaningful study needed to involve relatively large-sized samples. The definition of 'large size' is ambiguous too, as it is not clear what number would have been large enough to meet my requirement for relevant and significant research. However, the real problem was that it would have been impossible to obtain an in-depth and valid evaluation of the concepts that I wanted to explore in this study if I drew on a large sample using descriptive quantitative analysis. In contrast, a qualitative study would allow me to explore causes and effects that are more subtle and diverse.

3.2 Ontology and epistemology

3.2.1 An insight on quantitative and qualitative research

The choice of the used approach derived from the analysis of the differences between quantitative and qualitative methodologies in terms of their philosophical roots, focus, investigational goals, data collection approaches, and design, characteristics which led me to follow the latter (Denzin & Lincoln, 2018; Lincoln et al., 2018; Mahoney & Goerts, 2006).

Choosing a quantitative *versus* a qualitative approach here meant to 'take sides' between the two opposite philosophies, 'realism' and 'relativism', and between positivism and interpretivism, research paradigms of opposite ontologies (Clark, 1998; Kriukow, 2019, 2020; Rolfe, 2013), where the first refers to realism while the latter to relativism (Grant, 2017; Luboff, 2020). The positivistic approach looks at reality as one and measurable, governed by universal laws independent from an individual perspective. According to this, events and phenomena need to be broken into measurable elements which are investigated by looking for correlations and patterns. Perhaps, those elements will be attributable to a cause-effect law, and studied through a detailed and specific questionnaire, excluding anything correlated to human opinions or interests. In 1998, Smith wrote about the positivist view on social science research:

'Positivist approaches to the social sciences [...] assume things can be studied as hard facts and relationship between these facts can be established as scientific laws. For positivists, such laws have the status of truth and social objects can be studied in much the same way as natural objects' (p. 77).

The positivistic researcher must have no personal connection with the problem under study and be unemotional toward the people involved. Therefore, it seems clear that the positivistic approach is not suitable to perform social sciences research as (a) studying experiences and behaviours does not necessarily result in the measurements of numeric or categorical parameters and (b) it may be difficult for the researchers to analyse the experiences of the people involved in a study without (at least unconsciously) comparing them to their own.

For this reason, my study cannot be associated with the strict standards of a positivistic approach, as the interviewed teachers have their personal teaching approaches, resulting from their backgrounds, experiences, and schools they are teaching.

On the other hand, interpretivism approach relies on the investigation of multiple versions of the same reality, where each individual interpretation of the same phenomenon can be the consequence of a person attitude, feelings, perceptions previous experiences, gender, social background, or cultural beliefs. Interpretivism does not revolve around the measurement of data, rather it relies on the researcher's subjectivity, understanding, and interpretation. The interaction between the researcher and the participants in the research can be so strong that it is possible to assist to the co-construction of the reality under study.

The favourite research tool of a qualitative researcher is the in-depth interview, and this choice is an attempt to deepen the understanding of the phenomenon under study.

Popper and Kuhn gave a boost to post-positivist currents (Fuller, 2004; Kuhn & Hawkins, 1963; Nola, 1987; Popper, 2005), which included interpretivism, allowing the raise of qualitative methodologies, which were always been underrated with respect to quantitative ones. Their perspective on the development of scientific knowledge did not denature scientific research in terms of research, measures, and data gathering, but they instilled the germ of doubt in it. They opened to flexibility, to the possibility of choosing a paradigm, and eventually reject it with no eventual need of justification (Kuhn & Hawkins, 1963), or to the probability of false (Popper, 2005). This flexibility was the beginning of a wider opening to considering when and if everything needed to pass through the needle's eye of strict measurements, equations, and laws. And that is where qualitative research crept into and took the space it deserved, thus being finally considered an authentic *scientific revolution*.

Nowadays the pure positivist and interpretative approaches have been partially abandoned and a blend between positivist rigour and interpretivist multiple perspectives is preferred. Some researchers call this new approach critical multiplism (Guba & Lincoln, 1994, 1998), where *critical* refers to the positivistic approach characterised by *'rigour, precision, logical reasoning and attention to evidence'* (Crossan, 2003, p. 53) and *multiplism* to the multiple perspectives by which research can be approached. The multiple perspectives allow a better choice of the research goals, methods, analyses, and a more comprehensive hypothesis evaluation.

A rigorously structured approach based on a quantitative analysis would not have allowed me to deeply investigate the events and experiences that I knew I was going to analyse and describe in this study.

The flexibility associated with a qualitative method allows to start with a hypothesis on a certain number of events and then modify it to adapt to all or most of them, and this process results in new theories. In fact, qualitative research allows a flexible and in-depth descriptive approach through the exploration of a phenomenon to understand it, describe it, and finally interpret it. To achieve this result, the researcher needs to have an open and prejudice-free mind as it is the only way to interpret the meaning-making of the person who lived that specific experience. The resources of qualitative data can be interviews, observations, focus groups or existing documents (diaries, letters, etc.) and they can be used singularly or together for as long as the research development requires. Once collected, the data will be organised, converted into themes, and presented usually in a narrative or graphic form. The four major approaches to qualitative research are grounded theory, case study, ethnography, and phenomenology (Brown, 2010; Goulding, 2005; Starks & Trinidad, 2007). Grounded theory was the first method identified in qualitative research (Charmaz, 2014b; Glaser & Strauss, 2017) (mostly used in sociological research) and its data can come from different resources (*i.e.* interviews, focus groups, photos, existing documents, etc.); such resources are interpreted by coding them and dividing them into connected categories, and subcategories. Grounded theory uses a structured protocol to deal with a large amount of data on a long-term research basis, aiming to generate a theoretical level view of a certain phenomenon.

Case study is used in quantitative and qualitative research to study a process, an activity, or an event that involves one or more individuals (Forrest-Lawrence, 2019; Levy, 2008; Yin, 2013). It is used in several fields like medicine, law, but also media and communication, and depending on its purpose can be categorized as exploratory, descriptive or explanatory (Harder, 2010; Mills et al., 2013a, 2013b). Case study process begins with the study design where the research questions and the related framework are developed, followed by the study that might be conducted through interviews, surveys, questionnaires, document analysis or historical research. Once collected the data, the researchers will proceed to their analysis, resulting in a critical report showing connections between context and data collection, as well as the limits of the case studied.

The analytical description of an intact cultural group in terms of culture, values, beliefs and practices in its natural setting can be obtained through an ethnographic approach, which is based on anthropology and requires a prolonged observation time. It might involve the observation of small or large groups and can use quantitative data (Atkinson et al., 2012; Kaman, 1995) obtained by empirical observation in their natural settings.

Phenomenology sets its roots in phenomenological philosophy, whose major exponents were Husserl, Heidegger, Merleau-Ponty, and Sartre. Husserl believed that an in-depth human experience examination, through the phenomenological method, allowed the identification of the essential qualities of that experience. This deep knowledge of the experience, yet disregarding any particular circumstances, could become a benchmark for other investigators (Husserl, 2012). This approach was possible through a system of reductions, and thorough removal of researchers' biases and preconceptions with the aim of reaching eventually the essence of a given phenomenon.

Heidegger imparted phenomenology with a more hermeneutic approach compared to his mentor Husserl's transcendental view (Herrmann & Maly, 2013). He looked at human consciousness as the only thing making the world meaningful, reintroducing the concept of intersubjectivity, as the relation of a person in the world, with the world, and contextualized in the reality.

Merleau-Ponty contributed to phenomenology by defining *'mineness'* and *'aboutness'* of an experience, emphasizing the personal feature of the experience as depending on an individual view of the world in its wholeness (Merleau-Ponty, 2008, 2013).

Sartre founded the existential phenomenology which argued that a person is involved in continuous development and the existence comes always before essence. He argued that we are caught up in projects of the world, shaped by the presence of other people involved in their own projects (Copleston, 1949; Sartre, 2007), and the presence of people and things around us gives meaning to our experience of the world, as well as their absence. This is the basis of his idea of *nothingness*, where absent things are as important as the present ones defining our vision of the world. In this regard, my research is purely phenomenological as teachers' interpretation and expression of creativity is the result of an individual view (Merleau-Ponty) but contextualised and influenced by the reality they live in (Heidegger), and the people they met and contributed to their education (Sartre). Moreover, each experience studied is relevant and its interpretation is meant to be the starting point to further analysis (Husserl).

This study cannot be associated with the strict standards of a quantitative research, as it would not give a holistic view of the interviewees' teaching approaches, which are the result of their backgrounds, life and teaching experiences. Furthermore, quantitative research focuses on measurable parameters such as quantity, frequency and magnitude, while qualitative research is based on the quality or the meaning of an experience. A scholar who does quantitative research will collect the data through tests, surveys, *et similia*, whereas the most important tool in qualitative research is the researcher, whose role is fundamental to the analysis and interpretation of the 'meaning-making' of a person that has passed through an event (Holloway & Biley, 2011; Miles & Huberman, 1994; Watt, 2007). The investigation goal of a researcher involved in a quantitative study is to find correlations and make predictions or hypotheses based on an event, which is settled under controlled conditions and tested to confirm the previous assumptions. The qualitative approach, instead, is based on understanding meaning, describing, and along this process, defining a hypothesis and eventually discovering theories. Hence, quantitative research generally attempts to control all of the parameters that might affect the study of a specific event or phenomenon, while qualitative research is open to making course corrections, depending on any new conditions that occur (Bryman, 1984; Clark, 1998).

3.2.2 An informed qualitative choice

In the context of this research project, the data collection tool I selected was the semi-structured interviews, which allowed me to have an in-depth viewpoint on the idea of creativity and creative teaching by the people directly involved, the secondary school science teachers. This study was thought to gather information on teaching practices within a system that could not be fully controlled (Creswell, 2007, 2012;

Creswell & Poth, 2017) hence, a quantitative outcome would have been relatively difficult to achieve. This is the reason why, I did not write the interview questions to obtain quantitative data, but to pursue an in-depth analysis and to give meaning to the problem from a personal point of view, as qualitative research allows *'to make visible and unpick the mechanisms which link particular variables, by looking at the explanations, or accounts, provided by those involved'* (Barbour, 2019, p. 13). My study sought to identify the variables that may affect the use of creativity in science teaching and to do so, I wanted to understand teachers' ideas about this, to find the parameters that influence or limit them.

I planned to analyse the semi-structured interviews to secondary school science teachers through the lenses of a working definition of a creative lesson and an observation framework developed for this purpose. This meant an in-depth analysis and understanding of points of view, opinions, and the influence of environmental and social backgrounds, which are all factors that go beyond quantitative research. While quantitative research is structured and pre-determinate, it could be said that the keyword for qualitative inquiry is flexibility (Gavin, 2012; Holloway & Biley, 2011; Holloway & Todres, 2003), as it is more suitable to capture a loosely defined soft skill such as creativity within a lesson. The choice of a qualitative method is based on its subjectivity, and on the study of a limited number of cases, which nonetheless does not make it less rigorous. If my research had been based on numbers or a strict structured approach, I would not be able to enter deep inside the events or the experiences I am trying to describe and analyse. Furthermore, a qualitative description of one or more cases in their wholeness can be used as an imprint, as 'under construction' knowledge, to help to give meaning to or to explain the following aspects.

The flexibility and in-depth descriptive approach of qualitative research are embedded in the three steps that characterise the approach itself. The first step involves the exploration of a phenomenon, for an initial understanding. Once we understand this, we can move to the description of it, as its real core. The researcher needs to get close to the idea of the person who passed through the phenomenon, and how they went about it, but with an open and prejudice-free mind. Through this, the phenomenon can be better interpreted, and given its meaning. In qualitative research, the data gathering itself reflects the attempt to catch in-depth meaning; it uses interviews, observations and the study of existing documents (*e.g.*, diaries, letters), using these resources singularly or together, as soon as the choice of one or another becomes justified. Once collected, the data are organised, grouped into themes, and presented, quite often in the form of a narrative or graphics.

Such a phenomenological approach in qualitative research has its fundaments in the phenomenological philosophy, which is deep-rooted in my research project. The strength of the phenomenological approach with respect to grounded theory, case study or ethnography is the interpretative approach that it engenders. This offered the chance of carrying out an in-depth analysis while giving value to the single experience, not neglecting the opportunity of comparing each case in search of a common denominator (Brown, 2010; Gibson & Brown, 2011; Starks & Trinidad, 2007). In traditional grounded theory, the data come from different sources (*e.g.*, interviews, focus groups, photos, existing documents) and are interpreted by dividing them into categories and subcategories, thus creating connections and links (Charmaz, 2014a; Glaser & Strauss, 2017; Mills et al., 2006). However, this approach would not have fitted my research that is based on more limited data availability and required a psychological and empathetic approach. Case study approach is used nowadays in several fields, such as medicine, law, and also in media and communications, and depending on the purpose, it can be categorised as exploratory, descriptive or explanatory (Chaiklin, 1991; Mills et al., 2013a, 2013b). An exploratory case will generate the questions or the hypotheses that will be used by other researchers to develop new studies. A descriptive case will be a full description of an event in its context, and an explanatory case will be focused on the cause-and-effect relationships, to explain which cause produces a specific effect. In this regard, my research project features some of the explanatory case study characteristics, especially when considering the four steps involved in the development of a case study: design, execution, data analysis, and reporting on the results. Finally, the ethnographic approach, based on anthropology and founded on prolonged observation, follows analytical descriptions of an intact cultural group, with respect to culture, values, beliefs, and practice in their natural setting. It can be focused on either small or large groups and can also make use of quantitative data (Atkinson et al., 2012; Kaman, 1995). This approach will result in empirical data obtained in their natural setting, but these are not going to fit with a study (like the one presented here) that does not involve prolonged, possibly 'undercover', observations of many individuals, but instead relies on observations obtained by few individuals who are only linked by doing the same job.

3.3 Interpretative phenomenological analysis

Once recognised the phenomenological approach as the best analytical approach to my study, I decided to adopt the interpretative phenomenological analysis (IPA) which is an approach mainly used in psychology research. A plethora of alternative methods could have been used to perform my analysis but all of them had drawbacks that made them less suitable. In this regard, a phenomenological alternative to IPA might have been the phenomenological psychology adopted by Giorgi (1997) which uses a more descriptive approach with a continuous attempt to look mainly for commonality. Instead, the interpretative approach offered by IPA allowed me to look for points of convergency and divergency in the topics covered during the semi-structured interviews with teachers of different science subjects. Van Manen's hermeneutic phenomenological approach (Dowling, 2007; van Manen, 2016) is similar to IPA due to its philosophical roots, but it usually involves everyday practices associated with pedagogy and parenting studies. However, my research project was not related to parenting and neither to a straightforward pedagogic study, as it involved the teachers' approach to science teaching, the outcome of which is reflected in students' knowledge. Also, it did not involve an everyday practice, which violated one of the requirements suggested by van Manen.

IPA was developed in 1996 by Professor Jonathan A. Smith and it is based on the interpretation of an individual meaning-making of a certain experience (or phenomenon) (Smith, 2011; Smith et al., 1999; Smith & Osborn, 2008a). This approach assumes that the truth on a certain phenomenon is not objective, but deeply subjective, as the person who goes through a touching experience must be considered an expert on the meaning given to that experience. Consequently, the challenge for the IPA researcher is to face this personal meaning-making while looking for recurring themes, with the intent to a generalisation of some utility (Pringle et al., 2011; Smith et al., 2009a; Tuffour, 2017).

IPA has its roots in phenomenology, hermeneutics and idiographic, with each of them contributing to its development with the work of their major philosophers. The development of IPA is based on contributions from each of the major figures in phenomenology, like Husserl, Heidegger, Merleau-Ponty and Sartre. In IPA, the systematic analysis of the experience differs from Husserl's, as he tested the in-depth examination of an experience on himself, while IPA extends this to other people. The contribution of Heidegger to IPA is the vision of the human being dipped in a world of objects, relationships and languages, in a specific time and always in relation to something. Instead, Merleau-Ponty's influence on IPA was the view of the body as a central element in the experience, while Sartre's contribution was his view of the human body contextualised to personal and social relationships.

The connection of IPA with hermeneutic philosophy, which is by definition the philosophy of interpretation, is its attempt to interpret an individual meaning-making of an experience. It was influenced by Schleiermacher's holistic view, Heidegger's belief in the impossibility of reading without preconceptions, and Gadamer's importance of history and traditions (Heidegger & van Buren, 2008; Warnke, 1987). IPA embraced Schleiermacher's principle of obtaining significant insight into the interpretation of a text. Heidegger's view of phenomenology as strongly interpretative added to his hermeneutic will of arriving at an interpretation devoid of preconceptions, as the cornerstones of IPA. Gadamer argued that the researcher discovers their own preconceptions only when the interpretation has already started that again, as suggested by Heidegger, gets us close to the basis of IPA. The influence of ideography on IPA is evident, as they are both focused on the *sense of detail* and the *depth of analysis*, and they both believe in the possibility of inferring a meaning starting from a single and specific case (Smith et al., 2009, p.28). Studying the typology of a single case cannot be considered limiting, but a practice that exploits its interest and unicity (Chaiklin, 1991; Yin, 2003, 2009, 2013). It is not necessary to demonstrate its incidence, as it can open to things that we have not considered yet (Campbell, 1975), and drive us to a more general view (Heidegger, 1962; Heidegger & van Buren, 2008) in a way that is 'cleaned' of all fore-conceptions.

The importance of IPA does not only lie in the analytical attempt to move from the particular to the general, but also in its unique effort of speaking the language of the experience, whereby allowing the individuals that passed through it to express it in their own terms. The philosophical problem that emerges is that it will never be possible to get to the 'pure' experience, as once it is told, it has already happened, and we just witness it after the event. Therefore, the meaning given by the person that passes through a significant event becomes the experience itself, as it is the only representation of it, and that person will be the only one to be able to give any unique meaning to it. The researcher is deeply involved in the meaning-making of an experience or event made by a person, as well as in making meaning of the participant's interpretation.

This double interpretation means that IPA involves a 'double hermeneutic' process (Smith, 2011): the researcher is making sense of the participant's reading of the experience, who is making sense of it, which means that the participant represents meaning-making of the first order. At the same time, the researcher represents the meaning-making of the second order, which looks at the interpretation given by the participant through the lenses of a prior knowledge and experience.

IPA requires the researcher to 'dip into' the person's experience and to get an 'insider's perspective', while simultaneously being able to look at the participant's meaning-making of the experiences from a different perspective, as an outsider. The phenomenological approach of IPA requires the researchers to get as close as they can to the participant's interpretation, while the hermeneutical approach moves the IPA to the interpretation of the meaning-making of the experience. Having an insider's perspective does not mean that it is necessary to be an insider in each experience to be able to develop it; instead, it means to be open-minded, and get rid of preconceptions, without necessarily using theory-driven questions. This is also based on a strong knowledge of literature, with the ability to 'read' the meaning-making of the experience of the person who passed through it. Indeed, IPA can be considered a three-fold hermeneutics, as there is a third figure that has an interpretative role too, the reader. It is the reader who gives meaning to the meaning-making of the researcher, who has already developed that process with the participant in the study. Such an articulated system requires the use of a small sample of participants, where data collection is preferably performed through interviews or semi-structured interviews. While, data analysis involves the transcription of the data, followed by researching into any recurrent patterns of meaning (*i.e.*, themes) in terms of ideas, thoughts and feelings. This data gathering approach implies a key role for the researcher in the interpretation phase of the transcripts and the research of themes, and it also opens up chances of misinterpretation of the data due to any preconceptions or prejudices. A double, or more accurately three-fold, interpretative approach emphasises the subjectivity of IPA, which might not lead to a general theory, but allows an in-depth understanding of an experience. Also, it cannot be excluded that this experience might become a benchmark for further studies.

Thus, IPA allowed me to obtain personal meaning-making, a subjective perspective on creativity and the teachers' perception of science teaching as creative, without collecting data frequently. This result is generally achievable with a practicable sample dimension, which in studies such as the one described here corresponded to ten to fifteen teachers.

The choice of a limited number of participants involved in my research project was also a crucial difference with respect to choosing grounded theory approach.

Grounded theory based on sociological research was the first methodology identified in qualitative research (Charmaz et al., 2000; Glaser & Strauss, 2017; Mills et al., 2006), and it is quite often considered to be an *alternative* to IPA (Smith et al., 2009a, p. 201). It involves a large amount of data from different sources (*e.g.*, interviews, focus groups, photographs, existing documents) which are analysed through repeated coding procedures and finally grouped into subcategories. However, IPA does not require to work with a large amount of data or to get to general theories, but an in-depth analysis of every single case.

Phenomenology is a sub-set of qualitative methodologies, as well as grounded theory, case study, and ethnography, and such a schematic system is actually very flexible. Thus, we can look at IPA as being approachable through the same subcategories. The aforementioned grounded theory uses interviews and documents to collect the required data (Charmaz, 2006, 2014a; Glaser & Strauss, 2017; Mills et al., 2006), but the systematic application of grounded theory in IPA would lead to more abstract results, which would be exceptionally dispersive due to a large amount of coded data and the lack of in-depth analysis of each specific cases. An ethnographic approach to this study would have required full immersion and long observation time (Atkinson et al., 2012; Kaman, 1995), eventually introducing some bias due to my previous job position as a secondary school science teacher. However, both IPA and the ethnographic approach aim to build a relationship of trust using an empathetic approach with the participants to a study and share the same data gathering methods (*i.e.*, interviews, documents). Finally, a case study approach (Chaiklin, 1991; Newcomer et al., 2015) in its explanatory form is perfect for my study as it allows me to understand the cause-effect relation between factors influencing positively or negatively creativity and creative science teaching.

3.4 Sample selection

The selection of the sample in the IPA approach is never done *via* any probabilistic method but is instead driven by the purpose of the study. The participants are selected by the researcher as they are believed to have knowledge of the phenomenon to be studied. They can be contacted via referral, by responding to invitations, or through snowballing (Alase, 2017; Newberry, 2011; Smith et al., 2009a).

The selection of the group of people participating in the study, combined with the necessity for in-depth knowledge of the phenomenon through the words of the person who experienced it, drive the IPA researcher to select a small group of people for a study. However, the IPA sample has to be homogeneous, and this request generates some questions that need to be answered before the selection. The main question will concern which sample can be considered homogeneous, and the parameters that make it as such. The researcher is then driven to an interpretative choice of the sample.

For my research project, I initially decided to limit my selection to secondary school science teachers, with no limits set with respect to the number of years of teaching experience. This limit was considered not to be relevant, even though some interview questions concerned CfE which was introduced twelve years ago, so some long-serving teachers could also talk about teaching before that point. The contribution of a young teacher and that of a more experienced teacher had given therefore the same value. The teachers who started their teaching experience with CfE were generally those who had not experienced it while attending secondary school as students, and anyhow probably their idea of teaching was influenced by that experience. On the other side, more experienced teachers who used to teach when there was no CfE, and who have passed through the transition period, have now been teaching for twelve years with the new system. They thus have a perspective on the change and can evaluate how this influenced their work. A further requirement of the sampling approach included the participation in the study of teachers who specialised in all three sciences, *i.e.* Chemistry, Biology and Physics. In general, however, it was possible to divide the participants in the study into sub-groups according to the subject they were teaching.

This investigation was conducted online due to the COVID-19 pandemic which resulted in the schools being closed on the 23rd of March 2020 and prevented me to perform the data collection in person. I already had the Ethics Committee's permission to interview the secondary school science teachers online, and thus I proceeded with semi-structured interviews on the Zoom platform supplied by the University of Strathclyde. Unfortunately, once the schools opened again, the restrictions remained in place to avoid the spread of the virus, e.g. a second lockdown started during the Christmas break which again prevented my access to the schools. For the same reason, I could not conduct direct observations of class live lessons and I was forced to adopt instead the alternative solution of collecting some lesson plans from the teachers that I interviewed.

The selected sample was supposed to include a minimum number of ten teachers aged 21 years and over, and at least the equivalent number of lesson plans. I guaranteed a homogeneous sample in terms of disciplines taught, interviewing twenty-one teachers: one science teachers, six Biology teachers, eight chemistry teachers, and six Physics teachers. The participants were all volunteers who teach students of 12 years and upwards (*i.e.*, S1-S6). The sample of interviewees was enrolled via Twitter from all around Scotland, through a re-tweet cascade that started by tagging my supervisor, Dr Jane Essex, a highly experienced science educator who has over 2000 followers the majority of whom work in secondary education, and University of Strathclyde.

The process of enrolment was developed through snowball sampling, by asking teachers who would have liked to participate to suggest other colleagues who might be interested in the study (Noy, 2008; Wright & Stein, 2004). This approach used the professional network of early volunteers to extend the research population. The choice of the snowball sampling approach was meant to minimise the possibility of engaging with teachers who were not interested in being involved in my research topic. Science teachers were asked for permission to be interviewed, and where consent was not granted, alternative teachers were identified and approached instead.

The interview schedules are shown in the Participant Information Sheets (PIS; **Appendix C**). After distributing the PIS, the participants were given two weeks to evaluate this and decide whether to sign the correlated consent form (**Appendix B**) or not, which was not mandatory, in case they changed their mind about participating in the study.

3.5 Ethics

This study was submitted once to the Ethics Committee of the University of Strathclyde, then requested an amendment to the original method but for the same study and granted the committee's approval both times. Such a double submission was due to the COVID-19 restrictions which prevented me from observing the teacher's lessons as originally proposed and forced me to fold back to the collections of lesson plans instead, which required the Ethics Committee's approval. The relevant ethical issues for involvement in this study were the following (Baines et al., 2013; BERA, 2019; Boughtwood, 2007; Crozier et al., 1994; Noble & Smith, 2015; Orb et al., 2001):

- *Consent/ use of digital media – protecting data and identities*

The participation of the teachers was voluntary. The teachers contacted me as a result of the mentioned Twitter cascade, and they were invited to participate in online semi-structured interviews (**Appendix A**). With their permission, the interviews were recorded to maintain more accurate data gathering (Lunnay et al., 2015; Oliver et al., 2005). Following the Data Protection Act and the General Data Protection Regulations (Information Commissioner's Office, 2019; U. K. Government, 2018) on investigations involving human beings, they were given an informed consent form relating to the semi-structured interview before the data gathering commenced (**Appendix B**). They had the right to access the data stored that concerned them, and to request their destruction or withdrawal. Furthermore, they were offered the chance to see the transcripts of the interviews. The major concern was to protect the participants' reputations from damage. The transparency and openness of the research are embodied in the process, as the teachers interviewed were informed of the purpose of the research and the findings were shared with them at the end. The participants' email addresses were collected in a file stored safely in OneDrive, the Cloud-type storage application of the University of Strathclyde, with the transcripts and the audio recording. Furthermore, the access to my Strathclyde email account where I received their emails is password protected (**Appendix F**).

- *Privacy: anonymity and confidentiality*

The confidentiality and privacy of the participants were guaranteed by pseudo-anonymisation, through the association of specific codes to each of them that enabled the identification of subjects, with these codes and the collected data stored in OneDrive (**Appendix D**). The identification of the participants was made impossible to protect their professional reputation in case of sharing controversial material. However, I would not have upheld anonymity if anything said would have resulted in teachers' or their pupils' risk of harm. It was not possible to identify the participants in the output from the investigation. The semi-structured interviews were carried out in a private 'room' via Zoom, and the audio recordings were anonymised, as were the lesson plans.

- *Bias*

The questions of the semi-structured interviews were formulated to avoid the participants from being led in any way, and any indication of researcher's bias. This was achieved through a literature review and the evaluation of the questionnaire by experienced professionals, therein including my supervisors and Professor Simon Rees of Durham University (Baker, 2003; Cohen et al., 2017; Horton et al., 2004; Longhurst, 2009; McQuirk & O'Neill, 2013; Schmidt, 2004; Smith et al., 2009a). The questionnaire was divided into three main parts (**Appendix G**), the first two questions were meant to get an idea of the interviewee's previous working and teaching experience. The following five questions concerned CfE and its influence on teachers' jobs, whereas the last four aimed to understand teachers' ideas on creativity, creative students, the relationship between creativity and curriculum, and their approach to assessments. One focus of the questionnaire was the evaluation of the working definition of creativity and the flexibility allowed by the semi-structured interview allowed me to present my definition of creative lesson for teachers' evaluation without unveiling the author.

- *Coercion or power relationships*

The teachers could choose to participate or not, and there was no coercion, and no recording was performed without them being aware of it (Baines et al., 2013; Vanclay et al., 2013) (**Appendix E**). The participant teachers had two weeks to decide whether to participate or not in the study, and they could withdraw the collected data within four weeks of their interview before the transcripts were processed by the interviewer. A further consideration is that there were no penalties or adverse consequences of declining to participate or deciding to withdraw part of the way through. No 'backyard' or insider research was involved in this study, as I avoided interviewing teachers I already knew, or teachers working in the secondary school attended by my daughter. Interviewing teachers I already knew might have engendered a bias in my interpretation of the interviewee's words, eventually connected to previously shared opinions. Moreover, my role as parent and researcher would have generated a conflict of interest interviewing a science teacher at my daughter' school preventing me from going in-depth with my questions fearing to create any sort of discomfort.

- *Distress occasioned by discussion of sensitive topics or during a stressful period*

The semi-structured interviews were arranged considering each teacher's timetable, to avoid any interference with other commitments. They decided when the semi-structured interview could be conducted, and whether to allow me to attend any of their lessons. The interviews were arranged considering the comfort and well-being of the participants as a priority, and by all means, conducted in a comfortable and private environment. There were no additional risks to their day-to-day teaching and to the physical or mental well-being of the participants. The hazard associated with any potential loss of data or breach of anonymity was managed in line with the General Data Protection Regulation (Information Commissioner's Office, 2018, 2019; Van Alsenoy, 2019).

3.6 Data collection

The preferred approach to data collection was semi-structured, one-to-one interviews, although there are several examples of data gathering through postal questionnaires (Edwards et al., 2002; McQuirk & O'Neill, 2013), electronic email dialogue (Farmer & West, 2019; Turner et al., 2002), focus groups (Flowers et al., 2003; Palmer et al., 2010; Roose & John, 2003) and other observational methods (Larkin & Griffiths, 2002; Smith & Osborn, 2008a). The choice of a semi-structured interview allows access to the thoughts and feelings of the participants in the study, allowing teachers to put forward their ideas, rather than organising my questions with respect to a set of pre-determined categories (Horton et al., 2004; Salmons, 2015a; Smith et al., 2009a). Furthermore, the interviews need to be developed without the use of closed questions, but rather as open questions that allow the interviewees to open up, to talk about themselves. Although the questions were determined in advance, a semi-structured interview allows asking additional supplementary questions, as the name suggests. For example, I asked teachers about their idea of creativity and their feedback on my definition of creative lesson, but also if they taught in an affluent or a disadvantaged area. The attempt to create a comfortable and informal environment for the interview can have unintended consequences, in that they can lead the researcher to open up instead, to talk about personal experiences or give opinions that might influence the interviewee or drive the conversation off-topic. This should be avoided or left to the end of the interview.

The qualitative fundamental approach of this study was based on the experience of professionals. The variety of the sample was guaranteed by teachers from mainstream and special schools and offered a glimpse of the reality that teachers are facing at this time in the Scottish educational system. The participants were asked to select a location in which to conduct the Zoom interview whereby they would have felt safe and could engage in privacy. I was in a private room as well, with a neutral background and assured the participants that they could speak freely.

The interview agenda (**Appendix G**) comprised two sections: one was mainly focused on creativity and science teaching approaches, while the other mainly concerned the influence of CfE on teaching. The eleven questions of the questionnaire were developed to determine whether the teachers' approach to science teaching could be evaluated as creative, according to my working definition, and to what extent it could be considered affected by the CfE. The open questions were intended to give the teachers a chance to give their interpretation of the problem, by analysing their personal experiences more in depth.

I interviewed twenty-one secondary school science teachers, which is a higher number than traditional IPA samples, however, this choice was driven by the need to deal with the homogeneity of taught subjects and social background of the interviewees. Furthermore, I asked the teachers to show me schemes of their teaching approaches, or a set of lesson plans for each subject. However, only four teachers shared with me their lesson plans, and their limited number make it a source of data which cannot be correlated to the larger one gained from the semi-structured interviews. However, in the interest of a comprehensive knowledge, the lesson plans were reported in **Appendix L**. An original framework of creative features (**Figure 2.4**) was used to assess the congruence between the interview data, the curriculum material, and the pedagogical practice.

All of the collected data (*i.e.*, voice recording, semi-structured interview responses, lesson plans, analysis of the raw data) were held according to the Data Protection Act (2018) and the General Data Protection Regulations (2019) and were pseudo-anonymised (Information Commissioner's Office, 2019; Stead, 2018; U. K. Government, 2018; Van Alsenoy, 2019). The identification codes, data and analysis were stored during the data gathering session on a password-protected university computer and were uploaded as soon as possible onto a university cloud storage, where they were definitively encrypted and stored. Other Strathclyde academic staff were given access, by agreement, with the purpose of doctoral supervision. The physical material (*i.e.*, written notes) concerning the participants was stored in a locked cupboard at the investigator's workplace at the University and were only accessible by the investigator.

The data are expected to be held for up to five years, or until no longer required for further analysis, and during this period to be encrypted and stored. A simplified summary of the findings was agreed to be sent via email or mail (if requested) to the teachers involved, to whatever email address they prefer once the analysis was complete.

The participants were also informed that the analysis and findings (but not the raw data including audio recordings) were intended to be shared through professional conferences, and academic journals, although no details regarding the schools (*e.g.*, geographic location) were going to be shared under any circumstance.

3.7 Analysis

The data analysis of this study relies on IPA, which is usually used in psychology and based on the identification of themes and patterns following its phenomenological roots that are embedded in constructivism (Bodner, 1986; Schwandt, 1994; Sjøberg, 2010) and interpretivism (Kriukow, 2019; Sage, 2018; Schwartz-Shea et al., 2020). Therefore, an IPA researcher, whose work is the interpretation of an individual meaning-making of a certain experience (phenomenon), is very much guided by an epistemological background (Smith, 2011, 2018). Therefore, my challenge as an IPA researcher will be to face this personal meaning-making by looking for recurring themes (ideas, thoughts, feelings), with the intent of achieving a generalization of some utility. Identification of themes may proceed in a deductive or an inductive way. A deductive identification of themes would be driven by the researcher's theoretical or analytical interest, and result in a more detailed analysis of a specific aspect of the data. Instead, themes are identified in an inductive way if they strictly depend on data, and eventually might be reckoned in the researchers' questions, though it is necessary to make sure that bias or pre-concepts linked to their pre-existing frameworks, or theoretical interests will not affect the data analysis (Welch & Patton, 1992). With respect to the analysis of my data, using an IPA with a deductive approach meant identifying patterns that revolve around defining creative science teaching, preserving the will of keeping an open and prejudice-free mind which is an intrinsic characteristic of IPA (Boyatzis, 1998). This research has a specific geographic and political setting, namely Scotland, where the state school education system is guided by CfE. SNP has governed Scotland for the last twenty years and strongly promoted CfE as its programme, in opposition to the English education system (Education Scotland, 2019c, 2019d; Smith, 2016). It is crucial to remember that CfE influences the teachers not only in terms of the topics that need to be developed from the first year of the primary school to the sixth year of the secondary school but most deeply in their teaching approaches and workplace well-being (Convery, 2017; Priestley, 2010; Priestley & Humes, 2010).

Most of the literature on IPA concerns the field of nursing, and this is probably due to the psychological background of IPA. The use of IPA is, however, now well spread through many other research fields, and some interesting studies in education have been published recently, with some examples illustrating the approach being described below. An example of themes isolation embedded in the education field was proposed by Farmer and West (2019), who used an IPA study to examine the concerns that affected K-12 online teachers in an online school in the Midwestern United States. Although their study involved only seven teachers of one school, an in-depth analysis of the literature and the data gathered led the researchers to isolate six themes and design the related framework. I found this study relatable to mine at least in some parts, as the teachers I interviewed were experiencing online teaching although caused by the pandemic. Despite my study being meant to understand teachers' views on creativity, we could not avoid talking about the issues of teaching in a way they had never experienced before. All education systems based on face-to-face lessons were caught unprepared by the COVID-19 pandemic with respect to resources, such as electronic devices available to all students, internet platforms to be used, material to be shared, and assessments to be delivered. Furthermore, all these issues had to be considered in a wider attempt of protecting the mental health of youngsters and adults.

Another interesting study in the education field was one developed by Denovan and Macaskill in 2012 (2013), who used IPA to explore the stress that affects first-year undergraduate students when they move from high school to university. Their study involved semi-structured interviews with ten UK students who were studying criminology, sociology, psychology and politics, and it allowed the isolation of five main themes that were associated with the most useful coping strategies adopted by the students to overcome their problems.

Jeon and Othman (2016) published a study where IPA was used from a realist perspective, specifically in the acquisition of English for Academic Purposes as a second language of eight PhD students in a New Zealand university. The data gathering of this study was realised through multiple monthly interviews with the students over four to six months, and it demonstrated that IPA is suitable for understanding the complexity of real-life experiences.

During the online semi-structured interviews, which were video-recorded, I took notes throughout, and these notes were enhanced during the transcription phase. Following the IPA approach, I later compared the notes taken and the transcripts and started to isolate some categories which allowed me to define the assertions I used to disclose my data.

The transcripts' analysis was driven by the research questions (see **Section 3.1**) and by the need to understand teachers' idea of creativity and creative lesson. Furthermore, the answers to the research questions were inferred from the interview questions associated to them (see **Table 3.1**).

Table 3.1. Relationship between interview questions and research questions

Interview Questions	Relevant Research Question(s)
Do you feel any pressure or constraint upon how you deal with the Curriculum for Excellence (CfE)?	RQ2: What are teacher perceptions of CfE's expectations around creativity across the curriculum, and how do these expectations relate to the daily classroom practices of science teachers?
It is 10 years since the CfE was introduced. Do you think that it affected your teaching style? Or the way you used to plan your lessons? And if so, in which ways?	RQ2: What are teacher perceptions of CfE's expectations around creativity across the curriculum, and how do these expectations relate to the daily classroom practices of science teachers?
Do you think that the current national assessments provide a good measure of students' learning?	RQ3: What teaching approaches do science teachers report using to incorporate creativity into their lesson?
Are the assessments you use according to the CfE in the broad general education phase very different from the ones you use to prepare students for Nat-4 and Nat-5? If yes, can you explain why it is?	RQ3: What teaching approaches do science teachers report using to incorporate creativity into their lesson?
The CfE states that students need to be considered in a more holistic way, that is, in terms of their personal attributes, as well as taking account of their background. Do you think that the CfE gives you enough freedom to do that?	RQ3: What teaching approaches do science teachers report using to incorporate creativity into their lesson?
What does creative mean to you? Which is your idea of creativity? What do you think creativity means, or looks like, to your students?	RQ1: What do Scottish secondary school science teachers consider creativity to be in the context of teaching and learning science?
What personal trait do you associate with students you teach who are creative? Describe the profile of a typical creative student (e.g., extrovert, highly organized, self-assured).	RQ1: What do Scottish secondary school science teachers consider creativity to be in the context of teaching and learning science?
The CfE asks you clearly to teach in a way that would enhance the creativity of your students. In which ways do you meet this request? Do you think you have sufficient freedom or support to do it?	RQ2: What are teacher perceptions of CfE's expectations around creativity across the curriculum, and how do these expectations relate to the daily classroom practices of science teachers?
Do you prefer to pose your students open-ended problems or multiple-choice questions? Which questions do you think are more useful with respect to the development of creative thinking?	RQ3: What teaching approaches do science teachers report using to incorporate creativity into their lesson?

The analysis was developed by initially asking their opinion to a direct question (*What is your idea of creativity?*), followed by how they recognise a creative student (*What personal trait do you associate with the students you teach who are creative?*) and how they structured an assessment (*Do you prefer to give your students open-ended problems or multiple-choice questions?*). The total involvement of the researcher in the conversation with the interviewed teacher was possible due to the Zoom platform, which can record audio and video files. This allowed the researcher to perform an in-depth analysis during the transcription stage, which resulted in the isolation of more detailed impressions, and the evaluation of changes in tone and facial expressions.

As mentioned in **Section 3.4**, the years of teaching experience were not considered a factor influencing neither teachers' idea on creativity or creative science teaching, nor their opinion on the influence of CfE on their teaching. In this respect, IPA approach perfectly sit my research as it is based on the principle of giving value to every single experience and opinion. Furthermore, despite teachers with a few years of experience only experiencing an education system driven by CfE, they were considered qualified to evaluate its influence on their teaching. Besides, the youngest teachers (in terms of years of teaching) contributed with a fresh view on the current education system, looking at it compared to the older one they experienced as students.

Since teaching approaches, together with their outcomes, could be dependent on available resources, teachers were asked to comment on the area served by their school as I wanted to compare their opinion to the Scottish Index of Multiple Deprivation (SIMD), that is the value given by the Government to an area based on income, employment, education, health, access to services, crime, and housing (Scottish Government, 2020). However, the parameters considered by the Scottish Government appear to be not exhaustive as they only consider the material deprivation, and not the social one (Berthoud, 1976; Paterson et al., 2019; Townsend, 1987). In Scotland, an area is considered *deprived* if offering fewer resources or opportunities and is populated by low-income people. The material deprivation is more easily measurable, but the' social deprivation is equally important. Some examples of social deprivation might be people experiencing bereavement, personal or relatives' health issues, over-protective parents or guardians, and gender exclusion. These are just a few examples of social deprivation that cannot be 'measured' directly but affect the social life of a person **(Brown & Madge, 1982; Townsend, 1987)**. In **Table 3.2**, I reported teachers' perception of the school and the SIMD value of the area, which will be further discussed in the Results and Data Analysis chapter through Spearman's rank-order correlation coefficient and a scatter plot. This method is used to study the dependence of the ranking of two variables and returns a correlation factor r which is proportional to the association strength and a p-value, which is indicative of how much the correlation is statistically significant (*e.g.*, the probability that the observed correlation did not arise by chance). The coefficient r value ranges between -1 to +1, with the sign being indicative of a negative or positive correlation. The extreme values are returned when a perfect dependence between the variables is observed whereas values close to 0 are indicative of a poor association. On the other side, the *p*-value ranges between 0 and ∞, with values <0.05 being widely considered indicative of a statistically significant correlation. In general, when comparing two variables (or the same variable before and after) within the same group, a significative result of the Spearman's test means that there is a positive correlation (when both variables increase or decrease), or a negative correlation (when one variable increases and the other decreases) (see **Appendix H**).

I am aware that teachers' perception of deprivation is a subjective parameter, compared to external measures evaluated by SIMD, however, I think it can contribute to an evaluation of the social deprivation experienced by their students (see **Section 4.1.2**).

Table 3.2. Interviewed teachers, teaching subject, years of teaching experience, teaching area and corresponding SIMD

Teacher's name (Pseudonym)	Teaching subject	Teaching experience	Area served by the school (based on teachers' comments)	SIMD (Scottish Index of Multiple Deprivation – 2020)
1. Rachel	Science	30 years	Deprived	4d/ 2q
2. Laura	Biology	20 years	Deprived	3d/ 2q
3. Timothy	Biology	5 years	Mixed	1d/ 1q
4. Eloise	Biology	14 years	Deprived	6d/ 3q
5. Darren	Biology	17 years	Affluent	6d/ 3q
6. Simone	Biology	6.5 years	Affluent	7d/ 4q
7. Mark	Biology	10 years	Affluent	9d/ 5q
8. Laureen	Chemistry	13 years	Mixed	3d/2q
9. Jamie	Chemistry	3 years	Deprived	1d/ 1q
10. Laila	Chemistry	4 years	Deprived	6d/ 3q
11. Anya	Chemistry	2 years	Deprived	6d/ 3q
12. Karol	Chemistry	1 year	Mixed/ mostly deprived	9d/ 5q
13. Jerome	Chemistry	34 years	Mixed/ mostly deprived	5d/ 3q
14. Jacob	Chemistry	32 years	Very deprived	6d/ 3q
15. Alan	Chemistry	14 years	Mixed	7d/ 4q
16. Carter	Physics	14 years	Mixed	3d/ 2q
17. Joan	Physics	32 years	Mixed	4d/ 2q
18. Sandra	Physics	13 years	Very Affluent	7d/ 4q
19. Arthur	Physics	5 years	Very deprived	6d/ 3q
20. Harriet	Physics	4 years	Mixed/ mostly deprived	5d/ 3q
21. Stephan	Physics	35 years	Mixed	/

As mentioned, I had intended to interview the teachers in person, and observe some of their lessons, however the data gathering was accomplished during the lockdown and due to pandemic, I was not allowed to access the school therefore, I asked the interviewees to share with me some of their lesson plans, and four teachers (Laila, Carter, Joan, and Laura) shared them with me (Appendix L). Actually, most of the teachers did not have any, as they prefer taking eventually few notes on how delivering a topic instead of writing a detailed lesson plan.

The answers to the semi-structured interview questions allowed me to analyse the effect of CfE on science teaching. Furthermore, I developed a model representing creativity in school science, which can be achieved through creative teaching and teaching for creativity (**Figure 5.1**).

In **Appendix I**, are reported Jamie', Joan', and Simone' semi-structured interviews, which were acknowledged to be within the most mentioned one and meant to be representative of each discipline (*i.e.*, Chemistry, Biology, and Physics), moreover they have different teaching experience (*i.e.*, Jamie 3 years, Joan 32 years, and Simone 6.5 years). Furthermore, I thought it appropriate the appendix to contain at least one teacher who criticised or did not appreciate my working definition of creative lesson (Simone), as reporting only positive feedback would have given a biased view of the data.

IPA was thus used to investigate the interview transcripts, that as already mentioned, involves three people in the process: the reader, the researcher, who may be the same person, and the person who experienced the phenomenon directly. Hence, the subjective truth outweighs the objective one, as the participant is considered an expert on the phenomenon under study.

A qualitative approach such as the IPA allows access to data that would be inaccessible through a quantitative approach, as the core of this study is based on a personal view on creativity, a soft skill that has been hardly defined. Furthermore, each teacher has a different teaching approach engendered by previous experiences, by departments and school's rules, and by the audience, *i. e.* the students. Therefore, this study required an in-depth analysis combined with a certain degree of flexibility, which can be offered by a qualitative approach but not by a quantitative highly structured one.

3.7.1 Identifying themes and outlining findings

IPA researchers rely on theme isolation to analyse texts, such as letters, diaries, or transcripts. This analysis involves the identification of themes and subthemes, which once reduced to a manageable few, can be organised in a hierarchy of themes or codes, and eventually used to build theoretical models.

Themes are supposed to answer the question: *'What is this expression an example of?'* and come in all shapes and sizes. Some of them might be broad and link many different kinds of expressions, others are more focused and link very specific kinds of expressions.

When looking for themes, researchers can look for repetitions (1), in fact a concept repeated many times is more likely to be a theme, even if it is not settled how many repetitions are necessary to make a theme. Local terms that may sound unfamiliar or are used in unfamiliar ways (2) can result to be themes, and this approach is often applied in the ethnographic research or when interviewing focus groups. In a pioneering paper, Lakoff and Johnson (1980) observed that people often represent their thoughts, behaviours, and experiences with analogies and metaphors (3). Therefore, the researcher will be searching for metaphors in rhetoric, deducing the schemas, or underlying themes that might produce those metaphors. Even naturally occurring shifts in content may highlight themes. For example, in written texts, new paragraphs may indicate shifts in topics, whereas during a conversation, pauses, changes in voice tone, or the presence of particular phrases may indicate transitions (4). Glaser and Strauss (2017) used an approach based on searching for similarities and differences (5) by making systematic comparisons across groups of data. Another approach involves the identification of linguistic connectors (6), *i.e.* words and phrases such as *'because'*, *'since'*, and *'as a result'*, which often indicate *causal relations* or words such as *'if'* or *'then'*, *'rather than'*, or *'instead of'*, which often identify *conditional relations*, or even missing data (7). However, themes inferred from what is not mentioned might be the outcome of a biased approach as they may be a reflection of what the researchers are looking for.

In this study, the interviewees relied on concepts repeated several times, used linguistic connectors, and, in a limited number of cases, teachers used metaphors, such as, for example, *'thinking outside of the box'*. It was not recorded the presence of local terms used in unfamiliar context, although their presence cannot be completely excluded due to my lack of knowledge of typical expressions being a foreign student.

The concepts expressed by the different interviewees were compared looking for similarities and differences, and the analysis of the transcripts led me to look at "missing data" such as the SIMD index with the purpose of develop an in-depth understanding of the factors influencing a creative teaching.

The identified themes in this thesis took the shape of the findings reported in **Chapter 4** (**Table 3.3**), where the data were summarised and the repetitions, the linguistic connectors, the metaphors, and the similarities and differences between transcripts of different interviewees were pointed out in more detail through the use of tables. The choice of expressing themes through full sentences was driven by the imperative of capturing the meaning of teachers' words and translating the data into tables by the need of giving adequate weighting to their opinions.

This thesis is focused on the Scottish Education system and the findings were the result of an in-depth literature review and analysis of the transcripts. Hence, this study is settled in a specific context however, the findings and the assertions are believed to have a wider meaning applicable to different disciplines, or even to different geographical areas. This is the reason why it is fundamental identifying more specific sub-themes, within wider and general themes, even if these applications have not been explored in this study.

Table 3.3. Themes and findings

Finding	**Theme**	**Subtheme**	**Codes**
Teachers' view on creativity mostly agrees with the characteristics generally identify in literature (**Section 4.2.1**).	Characteristics of creativity identify in literature	Characteristics recognised by the Scottish science teachers	Novelty Originality Usefulness Meaningfulness Personality – Creativity relationship
The different curriculum stages support creativity discontinuously (**Section 4.3.1**).	Criticalities of the curriculum	Criticalities of CfE identify by the Scottish science teachers	Flexibility Performativity effect Resources (time, space, and money)
The routine practice of science teaching shows teachers striving to include creativity in their lessons. (**Section 4.4.1**).	Daily practice of creative science teaching	Characteristics of creative lesson	Novelty Interdisciplinarity Engagement
Teachers' plans for implementing creativity rely on curriculum knowledge, resources available, differentiated tests and building up relationships with pupils (**Section 4.4.2**).		Teachers' plans for implementing creativity	Assessments – creativity relation Student-teacher relationship Self-confidence – creativity relation

3.8 Trustworthiness

Trustworthiness in qualitative research has been considered an issue when compared to pseudo-antithetic quantitative approaches (Castellan, 2010; Noble & Smith, 2015; Sandelowski, 1986), because of its *subjectivity*. which means that the studied cases are described in their unicity, in-depth, and in detail. Quantitative research has always been carried out in an attempt to get to findings that have a general and uncontroversial meaning or application. However, the assumption that only a quantitative method can reach general conclusions or theories is false, as qualitative descriptions of one or more cases in their wholeness can be used as an imprint, as under-construction knowledge, to help to give meaning to or to explain a following case. The flexibility of a qualitative method allows to start with a hypothesis based on the observation of a certain number of events, and then modify it to adapt it to all, or most, of the events included, with this process potentially resulting in the generation of new theories.

I took several steps to ensure the trustworthiness of my research. First, transcriptions of the semi-structured interviews were only carried out by myself and were followed by the submission to my supervisors for approval of structure, and finally taken back to the interviewees to check for possible misunderstandings or missing statements. The participants in the study had the right to approve or not the transcripts, and they could withdraw them without any penalty if they changed their mind about participating in the study.

During this process, I had regular meetings with my supervisors to discuss the interpretation and selection of the themes, until I presented my final version for the evaluation of my conclusions, and this helped to ensure that my interpretation was plausible.

3.8.1 Context-based validation

This study aims to explore the role played by creativity in science teaching and to understand teachers' ideas of creativity, and how they recognise it in their students. Importantly, I do not assume any direct correlation between teacher delivering creative lessons and the enhancement of the students' creative skills, as it is necessary to distinguish between teaching *with* creativity and teaching *for* creativity (Davies et al., 2014; Tran et al., 2017). However, I explored teachers' opinion on the effect of creative teaching on students' creativity. Besides, studying the determinants of creativity in both teachers and students relies on the observation of certain characteristics during the lessons which should then be analysed in the context of a general framework and a working definition of creativity I produced and reported in more detail in **Chapter 2**.

3.8.2 Theory-based validation

Some scholars assert that there is a correlation between teaching the nature of science and an improved students' capability in problem solving and scientific creativity (see **Section 2.6.4**), however they highlighted the difficulty teachers find in delivering science referring to it. Therefore, I cannot demonstrate any connection between a creative lesson and the improvement of the creative skills of the students, but I made the assumption that the development of creativity is a process and a capability that can be enhanced in students through education (Kaufman & Beghetto, 2009; Koestler, 1969; Sadler-Smith, 2015). In this respect, I had an interesting conversation with Professor Rees (2020) of Durham University, where he argued that even if a creative thinking process can lead to *'good practice in teaching'*, a creative teaching is not *'going to automatically develop their (student's) sort of capacity of creative thinking'*.

Recognising creativity as a process and a capability led me to search for a working definition of a creative lesson (see **Section 2.7.2.1**). Writing this definition was a long process that required both a detailed literature search and discussions with teachers, education professionals and fellow PhD students. It was necessary to work on concepts that were at first abstract and that needed to be expressed in the correct way, as the use of one word instead of another could have resulted in limiting or emphasizing some of the underlying ideas. Generating a clear definition of creativity allowed me to recognise it during my investigation, and it also helped to develop the appropriate questions to ask the teachers during my interviews. Also, the CfE requirements for teachers to improve students' creative skills gave a further boost to my research, as I could cross-check the data I collected with the policy requirements imposed by the education system in Scotland (Education Scotland, 2019a, 2019c). I realised I did not need a realist approach, but a relativist one (Kriukow, 2019; Schwandt, 1994; Schwartz-Shea et al., 2020), which would allow me to proceed to an in-depth knowledge of the study I was pursuing, and to a detailed analysis of the collected data. Indeed, a positivistic approach would have meant referring to a quantitative approach, where looking at the experience as one and measurable, so governed by universal laws that are independent of the individual perspective.

The semi-structured interviews with secondary school science teachers are widely used in IPA, due to its phenomenological and hermeneutical approach to the teachers' experience and to the unique attempt of attending to the language of the experience, allowing the individuals that passed through them to express things in their terms (Smith et al., 2009a).

3.8.3 Response validation

The response validation was based on the definition of creative lesson, on the framework developed on the teachers' semi-structured interviews, and the related questionnaire.

As well as asking about their experience of creativity in school, I asked teachers whether they felt that my working definition of creative lesson corresponded to their understanding of the term creativity. I submitted this definition to all but one of the twenty-one teachers that I interviewed, but also to other education professionals and academics, and I received, in general, positive feedback. Indeed, I proposed my definition by the end of each interview once the interviewees had already given their definition of creativity and once each of them had recognised their teaching approach in at least some parts of the definition. My definition of creative lesson indicates how to recognise a lesson performed with creativity. As mentioned, this does not exclude the possibility that a creative lesson enhances the creative skills of the students but demonstrating this was not the purpose of this study.

The questionnaire that I wrote for the semi-structured interviews was composed of eleven questions with some of them which can be considered divided into sub-questions. This approach was chosen for the sake of clarity of the questions. I was rarely asked to explain any questions by a teacher (indeed, just once, at the time of writing). I originally planned to ask between ten and twelve questions which were expected to produce relatively short responses. However, this approach is inconsistent with the IPA methodology, and anyhow a phenomenological approach does not consider the use of closed answer as the interviewees might feel overwhelmed by this type of questions and inhibited (Adams, 2015; Schmidt, 2004). For this reason, I formulated each question considering the impact of them on the participants in the semi-structured interviews.

Notably, some caveats in using interview data are the variability on their conduct, the subjectivity in the interpretation, and the reflexivity, *i.e.* how the researcher might influence the process. In this regard, the better way to minimise any bias connected to both execution and interpretation is to be conscious of it. First, the researchers must understand their status as an insider or outsider researcher (Berger, 2015; Breen, 2007; Chavez, 2008). I considered myself to be an insider researcher as I had been teaching science in secondary school for eight years before starting my PhD. In this case, being an insider gave me the chance of being considered a peer and created the emphatic and trusting environment that was necessary to perform the interview with the teachers. Being an emphatic and supportive researcher might have been a double-edged sword, due to the bias that this may involve. However, the consciousness of being myself a teacher helped me not to emphasise my empathy to an extent that could bias influence the interviewees' answers. However, I can be considered an outsider researcher too, as engaged in my role as a PhD student and university researcher, and this aspect helped me to create the necessary distance between me and the participants in the interviews.

3.8.4 Criterion validation

The findings proposed in this study (see **Chapter 4**) are strictly connected to the themes isolated and validate the selection of criteria. Talking with teachers, I realised that there are problems with the idea of creativity, creative lessons, and how to improve the creative skills of the students, possibly due to the embryonic idea of what is creative, but also to the lack of an education path on this subject. Furthermore, the teachers experienced a certain degree of pressure from the National assessment requests, and therefore from the CfE.

3.8.5 Consequential validation

Since every model needs to be validated, I tried to engage in discussions with education professionals during the entire course of my PhD. Social events such as meetings, conferences and workshops offered me the most suitable environment for exchanging ideas with field experts and stakeholders.

In this regard, I was selected for a poster presentation at the first (2019) and second (2020) Multidisciplinary Symposium organised by the University of Strathclyde, and for a short talk at the School of Education Doctoral Showcase Event (2020). During the last two events, I had the opportunity to discuss the definition of creative lesson I was working on, which resulted in a unanimous appreciation of my work. Professor Rees of Durham University urged me to emphasize the difference between teaching with creativity and teaching for creativity and the concepts of *novel* and *usefulness*. Finally, the qualities of creativity I identify (novelty, originality, usefulness, and meaningfulness) are fully (one teacher out of twenty-one) or in part recognisable in teachers' answer to the questions *'What does creative mean to you? which is your idea of creativity?'*. In fact, seventeen teachers out of twenty-one mentioned at least one characteristic between the ones I selected. Furthermore, the working definition of creative lesson I wrote was recognised to be comprehensive of the characteristics a creative lesson is meant to have by seventeen teachers out of twenty.

3.9 Limitations

A large proportion of my PhD was carried out during the lockdowns due to the COVID-19 pandemic which resulted in my research activity being carried out mostly from home. I cannot deny that this event had an obvious negative impact on my work as it reduced the possibility of interacting directly and frequently with other professionals working in the fields or PhD fellows. But the main limitation imposed by the lockdowns was the inability of interviewing the teachers face to face and observe their lessons in a class context. The interviews had to be conducted online by using cloud-based video conferencing services such as Zoom which results in a less effective interaction due to the lack of 'reactivity'. Reactivity has been defined as the reciprocal response of the researcher and the participant in the study during the research process (Paterson, 1994). Identification of the sources of reactivity implies a better approach by the researcher in handling the research process. If we consider that IPA is based on the interpretation of an individual's meaning-making of a certain experience (phenomenon) (Smith et al., 2009a), the challenge of the researcher is to face this personal meaning-making by looking for recurring themes (*e.g.*, ideas, thoughts, feelings), to potentially reach a generalisation of some utility. The rising criticalities of IPA are mainly connected to the researcher's requirement to create an empathetic prejudice-free environment with the interviewee, to allow in-depth analysis of the experience. However, the presence of a computer screen between the interviewer and the interviewee affects their communication. Furthermore, the environment where the interview is performed is not the school anymore, and although being at home while interviewed might appear to be a comfortable and stress-free solution, this affects the trustful relationship between the researcher and the interviewee (Atchison et al., 2020). Let us not forget that the interview occurs between strangers, who had only communicated via email up to the moment they meet online. Therefore, the lack of a physical meeting can result in a certain degree of mistrust of an interviewer asking for personal information (James & Busher, 2006; Salmons, 2015a, 2015b).

These limitations had no simple solutions, and I tried to overcome them by introducing myself with a positive and open attitude. I explained to the teachers their total freedom to decide to withdraw at any stage of the study, and I reassured them that their data were going to be encrypted.

Notably, while the restrictions imposed by the pandemic resulted in the limitation described above, I made an effort to transform such drawbacks into an asset. In fact, the original pre-pandemic plan was to interview teachers in Glasgow and neighbouring areas. However, conducting online interviews allowed me to extend my study to schools that were far from Glasgow where my PhD was carried out. This resulted in gathering data and feedback that were peculiar of teachers working, for example, in rural areas.

3.10 Conclusions

In this chapter, I have described the process that led me to select a qualitative approach and a phenomenological method. I justified the choice of IPA through its connection to the characteristics of the data I was going to collect, and through comparing this approach with other phenomenological ones. Due to my scientific background and my involvement as a science teacher in a secondary school, I directed my attention to science teachers, their idea of creativity, and their subjective meaning-making of a creative lesson. I did so while considering all the reasonably foreseeable ethical issues that might have been involved, as confirmed by a double passage of my questionnaire to the Ethics Committee following the pandemic start and the consequent variation in the way the data were going to be collected. The trustworthiness of the research was analysed through recognised validity criteria (Alheide & Johnson, 1998; Noble & Smith, 2015; Whittemore et al., 2001). Every effort was made to recognise all the limitations associated with the IPA approach, combined with the challenging times when the data were collected, due to the restrictions of the pandemic.

Chapter 4. Summary of data

4.1 Introduction

This research concerns creativity and creative teaching, but its relevance is not confined to these domains, and I personally got evidence of this fact the first time I presented my findings on the characteristics of creativity. In fact, this topic mostly aroused the interest of people who did not worked in the Education sector, but in the Business and Economy field. This anecdote dates back to 2009 when I was selected to present a poster that was my first attempt of isolating and analysing the characteristics of creativity throughout a timeline at the first Doctoral School Multidisciplinary Symposium (DSMS) organised by the Doctoral Researchers Group (DRG) at the University of Strathclyde. Interestingly, the students and scholars who stopped by to ask questions about my research and latest findings were researchers of the Economics and Business departments and the questions concerned to what extent my findings could be applied.

4.1.1. Research questions and selected approaches to data analysis

The research questions which the study set out to answer and discussed in **sections 3. 1** and **3.7** are the following:

a. What do Scottish secondary school science teachers consider creativity to be in the context of teaching and learning science?

b. What are teacher perceptions of CfE's expectations around creativity across the curriculum, and how do these expectations relate to the daily classroom practices of science teachers?

c. What teaching approaches do science teachers report using to incorporate creativity into their lesson?

These questions shaped the literature review and supported the data analysis leading to answers which have been sought within the approach to creativity and creative science teaching of secondary school science teachers. The answers to the research questions inferred from the interview questions (see **Table 3.1**) took the shape of the following five findings, which will be analysed in terms of the data gathered in this chapter and discussed in Chapter 5:

1. Teachers' view on creativity mostly agrees with the characteristics generally identify in literature (see **Section 4.2.1**).
2. The different curriculum stages support creativity discontinuously (see **Section 4.3.1**).
3. The routine practice of science teaching shows teachers striving to include creativity in their lessons. (see **Section 4.4.1**).
4. Teachers' plans for implementing creativity rely on curriculum knowledge, resources available, differentiated tests and building up relationships with pupils (see **Section 4.4.2**).

4.1.2 Analysis of respondents

In this section, the profile of the interviewees and the role of the data collected about each respondent will be considered in forming the data analysis. Although I had hope to interview a comparable number of teachers from different subjects, I received a variable response to my call to take part in this study. As a result, I was able to interview six Biology teachers, eight Chemistry teachers, six Physics teachers, and one science teacher (i.e., qualified to teach Biology, Chemistry and Physics, with science). A minimum number of years of teaching experience was not required to take part to the study as this parameter was not considered linked to the emergence of the individual idea of creativity and creative teaching, in accordance with IPA principles. In fact, both newly qualified teachers as well as long-time experienced ones offered key contributions to the study. The former had a view on creativity influenced by their fresh view on the education system, whereas the latter had the chance of evaluating CfE's requirements on creative teaching comparing them to the previous education system's ones.

During the interviews, teachers were asked to share their lesson plans, although only four out of twenty-one (**Table 3.2**) reported having one. Among them, Carter and Joan, both Physics teachers, contributed with five lesson plans and one detailed project. Laura, a Biology teacher with a long-time teaching experience, sent me one lesson plan, while Laila, a young Chemistry teacher, sent me two. Most of the interviewees stated they did not project a lesson in advance and preferred to improvise instead and eventually taking few notes to improve their performance in the future. The limited number of lesson plans collected did not provide data to indicate teachers' views on creativity and on their creative teaching approach leading to exclude them from the data analysis. However, for the sake of completeness and clarity, they have been reported in **Appendix L**.

Performing semi-structured interviews online allowed to expand the quest for teachers willing to participate in this study to all of Scotland, whereas it would have been limited only to the Greater Glasgow area or the nearest surroundings. A snowball sampling approach was used to select secondary school science teachers to be interviewed and resulting in encouraging replies from teachers located mainly in Glasgow City, Edinburgh, North and South Lanarkshire, East Ayrshire, Dumfries, Galloway and the Highlands (**Figure 2.11**).

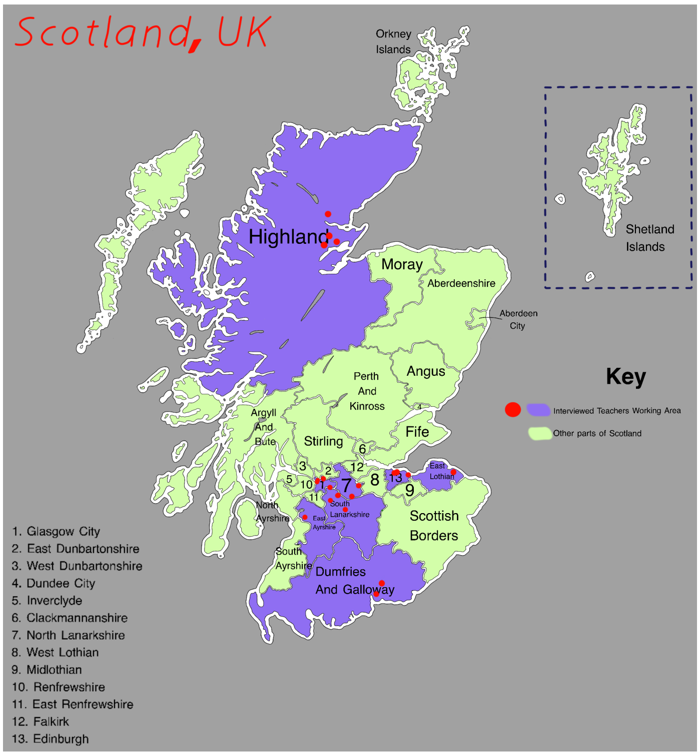

Figure 2.11. Location of interviewed teachers' schools in Scotland (Camiolo, 2022)

Table 3.2 shows teachers' perception on level of deprivation of their school's catchment area and the Scottish Index of Multiple Deprivation (SIMD) associated with that area (Scottish Government, 2020). These data were reported to explore if these two characteristics were relevant to their vision of creativity. Teachers' evaluation of deprivation is considered a reliable indicator, being the result of direct awareness of school resources and areas, and pupils' backgrounds. Therefore, the words *affluent/advantaged* and *deprived* are referred to the environment as seen by teachers in the context of the community the school serves. This approach strongly relies on the assumption that teachers are in the position of identifying social deprivation related to their students' background, family history, interests, and support they receive in school and, more generally, in life (Ellis et al., 2016; White & Murray, 2016).

Notably, teachers' perception of the school does not always mirror the issued SIMD score of the corresponding area. Such a discrepancy has been evaluated by using Spearman's rank-order correlation (see **Appendix H**) between these two parameters. Only numerical variables can be analysed using the Spearman correlation and therefore the categorical values relative to the teacher perception of their school were transformed into numerical by using the conversion factor as set out in **Table 4.1**. A plot representing the co-variation of the studied parameters is reported in **Figure 4.1** (see **section 5.3** for discussion).

Table 4.1. Conversion of teachers' observation into values to measure the Spearman's rank-order correlation

Very deprived	1
Deprived	2
Mixed	3
Affluent	4
Very affluent	5

Table 4.2. Conversion of teachers' perception of the school vs SIMD

Teacher's name (Pseudonym)	Area served by the school (based on teachers' comments)	Teachers' corresponding value	SIMD (d)
1. Rachel (S)	Deprived	2	4
2. Laura (B)	Deprived	2	3
3. Timothy (B)	Mixed	3	1
4. Eloise (B)	Deprived	2	6
5. Darren (B)	Affluent	4	6
6. Simone (B)	Affluent	4	7
7. Mark (B)	Affluent	4	9
8. Laureen (C)	Mixed	3	3
9. Jamie (C)	Very deprived	1	1
10. Laila (C)	Deprived	2	6
11. Anya (C)	Deprived	2	6
12. Karol (C)	Mixed/ mostly deprived	2.5	9
13. Jerome (C)	Mixed/ mostly deprived	2.5	5
14. Jacob (C)	Very deprived	1	6
15. Alan (C)	Mixed	3	7
16. Carter (P)	Mixed	3	3
17. Joan (P)	Mixed	3	4
18. Sandra (P)	Very affluent	5	7
19. Arthur (P)	Very deprived	1	6
20. Harriet (P)	Mixed/ mostly deprived	2.5	5
21. Stephan (P)	Mixed		/

(S) Science teachers/ (B): Biology teachers/ (C): Chemistry teachers/ (P): Physics teachers

The analysis resulted in a Spearman's correlation coefficient equal to 0.29, and a *p*-value of 0.21 (**Appendix H**).

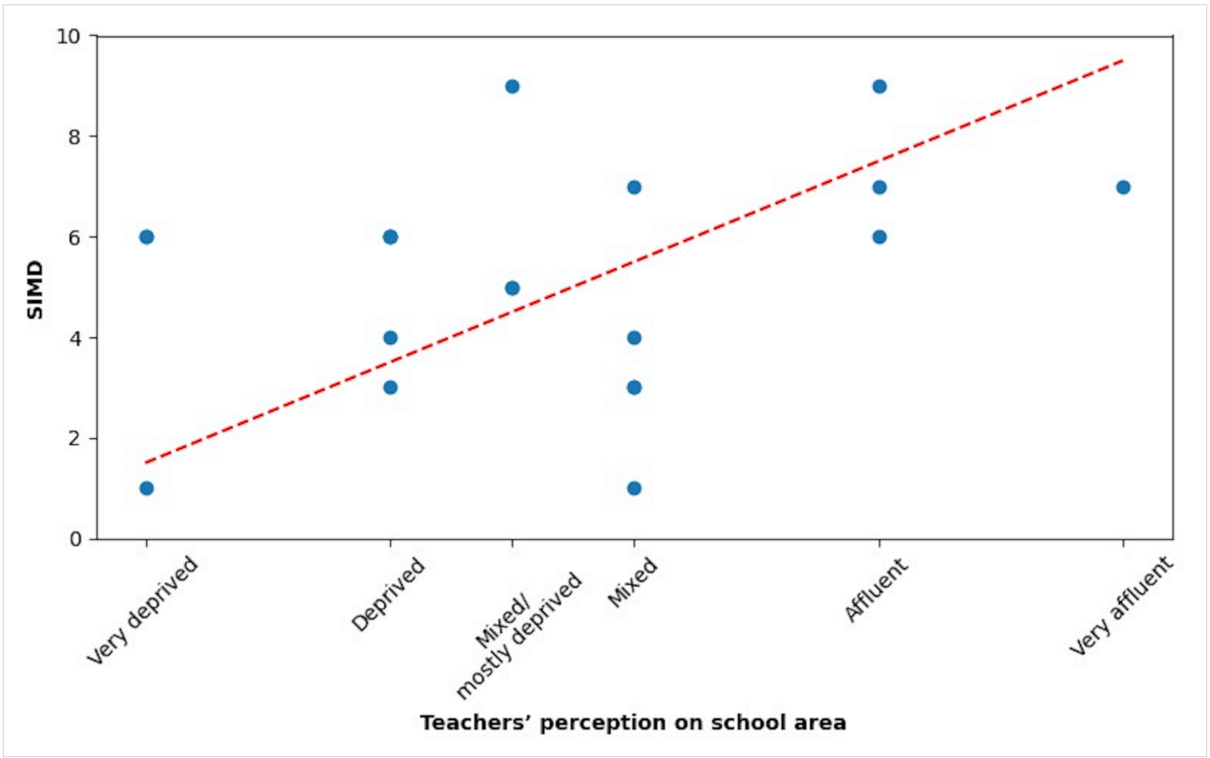

Figure 4.1. Scatterplot representing the co-variation of SIMD vs teachers' evaluation of the schools' areas

These results demonstrated a very low correlation between calculated SIMD levels and teachers' estimates, which is also highlighted a slightly positive trend in the scatterplot. The highest variability in the plot can be observed for median values of deprivation/affluence. Indeed, for a SIMD value of 6, teachers reported evaluations that spanned between *very deprived* and *affluent*. Similarly, teachers reporting a mixture of affluence and poverty in their area worked in schools located in areas with SIMD values ranging between 1 and 7. This observation suggests that teachers can consider the micro-level factors, whereas the SIMD levels are calculated at a meso-level which might include a number of schools. Furthermore, teachers tended, in the main, to over-estimate poverty.

4.2 What do Scottish secondary school science teachers consider creativity to be in the context of teaching and learning science?

The first finding (see **section 4.2.1**) provides an answer to this research question exploring the idea of science teachers on creativity and referring to the literature concerning its characteristics.

Today, science in school is still characterised by transmission issues as described in **section 2.6.3**, as pupils struggle to learn science due to the use of language or concepts too complicated to be internalized, requiring them to memorise instead of understanding. Moreover, a schematic teaching transmission, where the beginning and the end of the experiment are already known, contributes to turning off students' curiosity and will of deepening their knowledge (Johnstone, 1991). In this sense, a creative approach to science teaching, problem-solving and hands-on activities might lead students to learn science more effectively. However, in order to pursue this goal, it is fundamental for teachers to have a clear idea of creativity and its role in science teaching, therefore, in this study, teachers' idea of creativity was explored comparing it to the literature on this topic through semi-structured interview.

4.2.1 Teachers' view on creativity mostly agrees with the characteristics generally identify in literature.

As defined in **section 2.3**, creativity is the capability of generating meaningful and to a certain degree useful new and original ideas , and in this regard novelty, originality, and usefulness have always been considered characteristics of creativity (see **section 2.2**) (Amabile, 2017a; Bruner, 2011; Runco & Jaeger, 2012). Defining creativity as a capability rather than a quality means recognising it as an individual's potential to do something new and original when facing particular situations or problems for the first time, *i.e.,* it can be enhanced or diminished, but it can be shown by anybody. For this reason, creativity is not considered as belonging to few individuals with privileged access to elite education or funds, but rather accessible to everybody and a capability able to improve our everyday life (Helfand et al., 2017; Richards, 2007).

An analysis of the interviews' transcripts allowed me to investigate whether the characteristics of creativity described in **section 2.3** were reported in teachers' answers. Besides, the characteristics of creativity were inferred through an in-depth analysis of CfE leading to the results reported in **Table 4.3**. Among the features of creativity, I added its dependence on resources such as time, space and money, which at this stage of the analysis I consider influencing the possibility of delivering creative teaching.

Table 4.3. Creativity features in teachers' interviews and in CfE

Creativity features	**Teachers' opinion on creativity features**	**Creativity features in CfE**
Novelty	✓	
Originality	✓	✓
Usefulness	✓	✓
Education dependent	✓	✓
Social status dependent		✓
Personality dependent		✓
Dependent on school's resources (time, money, spaces)	✓	

Most of the teachers often used the three main characteristics of creativity, *i.e.,* novelty (often expressed by the terms *new* or *innovative*), originality, and usefulness to describe it and in response to the questions *'What does creative mean to you? which is your idea of creativity?'* or commenting on my working definition of creative lesson (see **section 2.7.2**).

For example, Jacob believes that the expression of creativity involves *'making something new, in some respect'*. In this respect, Alan, who teaches Chemistry by using his passion for magic to deliver creative lessons, emphasises this interpretation by defining being creative as, *'creating something that is unique to you, that no one else has done, that pupils would like to see, and helps'*.

In some cases, additional features of creativity, such as imagination, have been suggested by the interviewees. For example, four teachers consider it an important element of creativity. Jerome recognises creativity as an *'imaginative process'*, whereas

Rachel, a Chemistry teacher in the Highlands, thinks that students should be allowed to *'use their imagination, to pull things together, and to think of new ways of putting it if you like, to create new ways of expressing it'*. Furthermore, she believes that the creative process needs to be supported by an appropriate environment, as *'creativity is about giving people the space to think creatively; like to ask those questions "what if", you know'*.

However, the idea that creativity as mainly related to arts is still deeply rooted in some teachers, who believe their students share the same sentiment. Harriet, a Physic teacher in a deprived area (SIMD 5), believes that her students recognise *'something crafty'* as creative while Anya relates creativity to *'how people express themselves through kind of art, or performance'*, although describes a creative person as:

'Somebody who can think up ideas that are quite innovative [...] think of ideas which are new and fresh, and [...] then, put them into practice'.

4.2.1.1 Summarising teachers' view on the working definition of creativity

The recognisable keywords of the working definition of creativity, which led the development of my definition of creative lesson are the terms *new*, *original*, *meaningful* and *useful* (see **section 2.3**), which together with their synonyms or equivalent expressions arose during the analysis of the data transcripts.

Teachers recognise creativity as being manifest when pupils create connections, ask questions, or in self-expression, but more in general in doing things in a novel way. In this regard, **Table 4.4** reports how teachers defined creativity, answering the questions *'What does creative mean to you?'* and *'what is your idea of creativity?'*.

The third column of **Table 4.4** shows which key features were recognised to be present in teachers' definitions of creativity. If neither of the keywords nor their synonyms could be found in teachers' words, the sentences were investigated to identify whether a key feature was expressed in a more implicit way and if so, it was reported between brackets. For example, Darren did not use any keywords or related synonyms, but he described his teaching approach as based on the use of any available resource to create a novel and original product. Similarly, whenever teachers talked about engaging students and raising their interest in the topic under study, I recognised the usefulness or meaningfulness they put in their creative product.

Table 4.4. Teachers' definition of creativity with keywords relating to the working definition of creativity highlighted (part 1/2)

Teachers' name (Pseudonym)	Teachers' definition of creativity	Key features found in my definition of creativity
1. Rachel (S)	*'Creativity is, is people being able to have that, to use their imagination, to pull things together, and to think of* ***new*** *ways of putting it if you like, to create a* ***new*** *way of expressing it. That's how inventions and development all happens […] Creativity is about giving people the space to think creatively, like to ask those questions 'what if…?', you know. To have the freedom to express themselves in a different way and to share their ideas in a different way'.*	Novelty/ Originality
2. Laura (B)	*'I think (that creativity) for science, I think it's learning something* ***practical****'.*	Usefulness
3. Timothy (B)	*'To me creative would be getting away from your chalk and talk blackboard teaching. To me, creative can be (.), it could be in the way I deliver something, it could be the way I ask, what I get the pupils to do, what I get them to deliver. It's making lessons interesting; it's getting pupils to actually kind of think themselves. It could be the way I'm using different ways to convey within a class, using different mediums'.*	(Novelty/ Originality/ Usefulness/ Meaningfulness)
4. Eloise (B)	*'Creativity is the, just the chance for a child to be able to express themselves and have a bit more freedom of choice in what they want to do'.*	-
5. Darren (B)	*'Creativity, obviously, for me I think about imagination, and getting the kids to use their imagination. And to try and present information to the kids […] in various different ways, you know, trying to use as many resources at my fingertips as I can'.*	(Novelty/ Originality/ Usefulness)
6. Simone (B)	*'I think, for me, the kind of creativity is a kind of energy, that I describe as a type of energy, because I access it in different ways, like an energy. I access it sometimes by something that I just have this sense of, this needs to take these disparate, disparate parts, and pull them together somehow, and make something, make something, that doesn't have to be something new. It doesn't have to have this kind of new innovative, that's something different, that's* ***innovation*** *in this way. But creativity to me is about taking these different elements, these different parts, this different things, different ideas, and it's the act of bringing them together, assimilating them into some kind of sense, some kind of order in your brain, or your body, and then putting them back out there'.*	Novelty/ Originality
7. Mark (B)	*'(Creativity) is all about coming up with* ***new*** *ideas. The way that we speak about it is that science is about observing a phenomenon, and then you observe it, and then you design an experiment to test it. And without creativity, how can you design?'.*	Novelty/ Originality
8. Laureen (C)	*'(Being creative means) that pupils don't know what exactly (.), what to expect in every lesson, maybe there's some routine but they're not exactly sure about the activities, they're going to do in a lesson, and so (..), they're going to, maybe, experience some things that will engage them better […] I suppose if something's creative other teachers will probably go, 'Oh, that's a good idea. Tell me more about that''.*	(Novelty/ Meaningfulness)
9. Jamie (C)	*'Thinking outside the box to solve maybe problems, trying to be* ***innovative*** *in your approach to things, as a teacher employing versatile teaching methods as part of creativity'.*	Novelty/ Originality
10. Laila (C)	*'Creativity is using different, different ideas, when I'm teaching. […] Creativity, for me, is using different techniques, different tools to get my learning across. […] I'll give them anecdotes, make a fool of myself if it makes something* ***new*** *for them to understand'.*	Novelty/ Originality

(S) Science teachers/ (B): Biology teachers/ (C): Chemistry teachers/ (P): Physics teachers

Table 4.4. Teachers' definition of creativity with keywords relating to the working definition of creativity highlighted (part 2/2)

Teachers' name (Pseudonym)	Teachers' definition of creativity	Key features found in my definition of creativity
11. Anya (C)	*'Creativity for me would just be how people express themselves through kind of art, or performance, or the way that, in the way that they work. If you're a creative person, you're somebody who can think up ideas that are quite* ***innovative****, and (.). If it's to me, it's not so much like can you draw, can you, can you play a musical instrument, that's more just can you think of ideas which are* ***new*** *and* ***fresh****, and are you able to, then, put them into* ***practice****'.*	Novelty/ Originality/ Usefulness
12. Karol (C)	*'Creativity for me as a teacher, for me, personally, it means getting away from the traditional idea of the lesson as much as possible in a way, like not be standing there at the front with slides with text on them that they copy down. If I can, I want to try and make every lesson creative in that it does far more active learning […] the ideal of creativity that doesn't always line up, is giving them a bit more choice, and giving them a bit more control over what they're learning'.*	(Novelty/ Originality)
13. Jerome (C)	*'Creativity is linked with imagination. It's an imaginative process. It links in with confidence, with courage. […] when I'm teaching the Higher chemistry, for example. I would give them a choice of which variable to look at. So, well, we did it recently with the last year higher class, we were looking at reaction rates, and some of them choose to vary the temperature, some of them choose to vary the concentration of the acid. I mean, that's quite a limited, that's a binary choice. But that's that as a kind of creativity, rather than missing rate 'you do temperature, you do concentration'. […] I let them choose that is a sort of kind of creativity. […] creativity is kids have to be confident before they can be creative. I think, especially as you go up, especially as you grew up through the years in high school, you become more risk averse, and great risk for a teenager is a social capital'.*	-
14. Jacob (C)	*'I think of being creative in making, making something that's* ***new****, in some respect'.*	Novelty/ Originality
15. Alan (C)	*It's doing something, you're creating something* ***unique*** *to you, that no one else has done that pupils would like to see and* ***helps****'.*	Novelty/ Originality/ Usefulness
16. Carter (P)	*'Being creative, to me, is using, well, as a teacher being creative, means using what I know and the experience I've got to try and make what I'm trying to teach in a way that interests people, and to try and meet what I'm teaching engaging, inspiring creativity in the students is about them learning to apply what they know, and apply the skills that they're developing in a flexible way.*	Usefulness/ Meaningfulness
17. Joan (P)	(she did not comment on creativity)	-
18. Sandra (P)	*'Creativity is being able to teach things in a way that inspires interest in the subject, as opposed to focusing on content'.*	(Usefulness/ Meaningfulness)
19. Arthur (P)	*(Creativity is about giving the students) a bit of creative freedom in within they're to be able to work around, but we don't necessarily have it in a lot of the topics […] (Creativity is to) give them (the students) that creative freedom of expression'.*	-
20. Harriet (P)	*It's them trying to do something in a slightly different way, or something that's not just chalking talk. For me, that anything they do outside of that is creative. […] creativity, for me, that is using different techniques, different tools to get my learning across'.*	(Novelty/ Originality/ Usefulness)
21. Stephan (P)	*'Creativity is actually coming up with* ***new****,* ***new*** *knowledge artifacts, whatever it is, you know, and, and, you know, changing what you do, how you do it, what you produce, compared to what's gone before, you know'.*	Novelty/ Originality

(S) Science teachers/ (B): Biology teachers/ (C): Chemistry teachers/ (P): Physics teachers

Eloise, Jerome, and Arthur described creativity as an imaginative process where the driving force is students' freedom of expression, an idea that does not correspond to any of the key features of the proposed definition of creativity. In fact, Jerome despite the lack of straight reference to the key features of creativity, talked about courage, and self-confidence, whereas Joan did not provide a definition of creativity but talked extensively about her teaching approach and her idea of creative students.

Fourteen teachers out of the twenty-one teachers interviewed recognised novelty as a characteristic of creativity. Timothy, who filled his classroom with posters made by students and during his lesson wants them to sit around him eventually moving their desks, talked about abandoning *'chalk and talk blackboard teaching'*, using any *'medium'* available to engage students in the lesson. Harriet agrees with him in dropping anything that is *'chalk and talk'* but using different *'techniques'* and *'tools'* to breach in her students' interest. Timothy and Harriet use the expression *"chalk and talk"* referring to a teaching practice which does not engage the pupils in the lesson but treats them as passive learners, vessels that need to be filled. And, in this respect, Joan expresses her concern regarding students looking forward to copying from the board: *'[…] Why is anybody copying from the board in 2020? And you, and you go around the classrooms, and they're copying from the board and the kids want to do that. And there's no place for that in science'*.

These results (see **Table 4.5**) show that besides teachers recognising novelty as a characteristic of creativity, originality is acknowledged by thirteen of them.

Table 4.5. Creativity key concepts in teachers' definition of creativity

	Key concepts			
Teacher's name (Pseudonym)	**Novelty**	**Originality**	**Usefulness**	**Meaningfulness**
1. Rachel (S)	✓	✓		
2. Laura (B)			✓	
3. Timothy (B)	✓	✓	✓	✓
4. Eloise (B)				
5. Darren (B)	✓	✓	✓	
6. Simone (B)	✓	✓		
7. Mark (B)	✓	✓		
8. Laureen (C)	✓			✓
9. Jamie (C)	✓	✓		
10. Laila (C)	✓	✓		
11. Anya (C)	✓	✓	✓	
12. Karol (C)	✓	✓		
13. Jerome (C)				
14. Jacob (C)	✓	✓		
15. Alan (C)	✓	✓	✓	
16. Carter (P)			✓	✓
17. Joan (P)				
18. Sandra (P)			✓	✓
19. Arthur (P)				
20. Harriet (P)	✓	✓	✓	
21. Stephan (P)	✓	✓		
Total	14	13	8	4
Proportion	0.67 14/21	0.62 (13/21)	0.38 (8/21)	0.19 (4/21)

(S) Science teachers/ (B): Biology teachers/ (C): Chemistry teachers/ (P): Physics teachers

All teachers' idea of creativity where I recognised the concept of novelty contained the originality one as well, except one. It was difficult in fact finding words or expressions leading me to the concept of originality within Laureen's definition of creativity.
On the other hand, only a few teachers identified usefulness (eight teachers) and meaningfulness (four teachers), as important features of creativity. At a first interpretation of transcripts, teachers explicitly recognising the value of usefulness and meaningfulness were quite few. In fact, an explicit sentence as Carter's one, who argued that is creative what *'students are able to use'* or that being creative *'is using different techniques, different tools to get my learning across'* was not common.

After interviewing the first six teachers, I realized that one of the questions I asked them, namely *'The CfE asks you clearly to enhance the creativity of your students. In which way do you meet this request? Do you have sufficient freedom or support to do that?'* (Question A), could be considered as an extension of the more specific question: *'Do you think that teaching in a creative way, enhance students' creative skills?'* (Question B). The answers to Question A showed teachers' attempt to project *'more types of tasks, and different styles of assessments in ways that they can be creative throughout it'*, as mentioned by Timothy, activities that all students could approach following their own skills and interests. One of his students, for example, during the first lockdown filmed himself transforming a chemistry lesson into a cooking one, an idea that was welcomed with enthusiasm, though *'really really hard from a teacher perspective to assess'*. Joan instead developed the heat topic asking her students to project a testable experiment that could allow them to evaluate the heat loss of a house, and no choice was precluded in this task, except stopping at first attempt, as *'we're teaching them to be creative, to come up with ideas'*. However, the enthusiasm showed by four teachers out of the seven answering Question A was clouded by the concern expressed referring to the delivering of creative activities during the Senior phase when the lack of time due to the upcoming National assessments is perceived. Harriet, for example, despite her attempt to *'give them* (the students) *as many opportunities as possible to design an experiment,* *to decide how they're going to allocate things, or they're going to work through that'*, believes they *'get more freedom and more ability to do that in terms of homework [...] rather than classwork'*. The result of this investigation is reported in the last column of **Table 4.6**.

Table 4.6. Creativity key concepts and teaching for creativity

	Key concepts				**Creative teaching resulting in teaching for creativity**	
Teacher's name (Pseudonym)	**Novelty**	**Originality**	**Usefulness**	**Meaningfulness**	**Question A**	**Question B**
1. Rachel (S)	✓	✓				✓
2. Laura (B)			✓		✓	
3. Timothy (B)	✓	✓	✓	✓	✓	
4. Eloise (B)						✓
5. Darren (B)	✓	✓	✓			✓
6. Simone (B)	✓	✓				✓
7. Mark (B)	✓	✓			✓	
8. Laureen (C)	✓			✓		
9. Jamie (C)	✓	✓				✓
10. Laila (C)	✓	✓				✓
11. Anya (C)	✓	✓	✓			
12. Karol (C)	✓	✓			✓	
13. Jerome (C)						
14. Jacob (C)	✓	✓				✓
15. Alan (C)	✓	✓	✓			✓
16. Carter (P)			✓	✓		✓
17. Joan (P)					✓	
18. Sandra (P)			✓	✓	✓	
19. Arthur (P)						✓
20. Harriet (P)	✓	✓	✓		✓	
21. Stephan (P)	✓	✓				✓
Total	14	13	8	4	7	11
Proportion	0.67 (14/21)	0.54 (13/21)	0.38 (8/21)	0.19 (4/21)	0.7* (7/10)	1** (11/11)

(S) Science teachers/ (B): Biology teachers/ (C): Chemistry teachers/ (P): Physics teachers

* = this proportion is calculated by considering teachers whose answer has been extrapolated by Question A

** = this proportion is calculated by considering teachers who answered Question B

Eleven teachers interviewed on Question B provided only positive answers, whereas question A was interpreted as teachers' belief that creative teaching enhances students' creative skills in seven cases of the other ten. This analysis resulted in eighteen teachers over the twenty-one interviewed acknowledging that their job enhances students' creative skills, and I interpreted this as them recognising their work of promoting creativity as useful and meaningful. Interestingly, two teachers highlighted that some action is necessary for creative teaching to result in enhancing students' creativity. Mark, for example, made a clear distinction between him being creative and letting the students be creative:

'I could be creative by designing a new experiment and showing a new experiment to pupils. However, for me, that's me being creative in my approach, but if I wanted them to be creative, I would give them all the apparatus that they need. […] I think that creativity is a skill, and the only way to develop a skill is to practice it. And so there must be a practical element to creativity somewhere'.

On the other hand, Harriet highlighted that only by using different approaches to teaching topics we can enhance students' creative skills:

'That's about ensuring that when you're teaching, you're using a variety of different approaches. […] I think that there are certain teaching strategies, that are more effective for certain topics […] there needs to be an element of creativity and using a variety of approaches to help the learners to learn […] different things. And I think that that rubs off a little bit into […] creativity of the learners because they're exposed to a wider range of experiences'.

Eight teachers further pointed out that creative teaching as a tool for improving creativity in students can mainly be attempted during the BGE. During this period, for example, Laura developed her lessons by using activities that engaged students in fields that were interesting to them such as Harry Potter, Cluedo and mystery crime. In fact, she argued that *'creativity in teaching styles or activities can help to reinforce their* *understanding'* as *'there is definitely room for creativity is just trying to work it in around the content'*.

Timothy agreed with Laura's opinion on the extent of freedom allowed during the BGE and emphasized the importance of department support and the need of having a common vision, *'I do think we're definitely bringing in more, more types of tasks, and different styles of assessments in ways they can be creative throughout it'*.

In Anya's words it is possible to recognise novelty, originality and usefulness as characteristics of creativity, and in her idea of creativity she clearly showed her thought: *'You think of ideas which are new and fresh, and you are able to, then, put them into practice'*. Laureen's idea of creativity clearly refers to characteristics such as novelty and meaningfulness and interestingly she is the only one who evaluated her creative teaching through the words of her colleagues: *'I suppose if something's creative other teachers will probably go, 'Oh, that's a good idea. Tell me more about that'*.

In conclusion, twelve teachers out of the twenty-one interviewed recognized all the characteristics of creativity (see **Table 4.6**). This sample is quite heterogeneous in terms of years of teaching experience which span from one to thirty-five years, furthermore it is composed of teachers working in deprived areas as well as in affluent ones. Within this group of teachers, five of them teaches Chemistry, four are Biology teachers, two are Physics teachers and one teaches science.

Jerome who has an experienced of thirty-four years as Chemistry teacher is the only one whose idea of creativity cannot be classified within the four characteristics. In his opinion, creativity is linked to imagination, which develops through an *'imaginative process'*, and in order to use their imagination, students have to be confident in approaching the topic under study and confident in manipulating the topic itself. In this respect, the teacher is fundamental in giving students the freedom to use that imagination, in fact he argued '*I let them choose and that is a sort of kind of creativity […] encouraging the kids to, to bring something of themselves into the lesson'*.

4.2.1.2 Creativity and personality

Many scholars explored the relation between creativity and personality (Feist, 1998; Oleynick et al., 2017; Sternberg & Kaufman, 2018) and in this regard, during the semi-structured interviews, I asked teachers which personality trait they recognise in the students whom they consider creative. The question (*What personal trait do you associate with student you teach who is creative?*) resulted in a nearly unanimous response as nearly all of them (eighteen teachers out of twenty-one) agreed that creativity is independent of personality. Even characteristics such as being extroverted or an introvert and being organized or disorganized were not associated with creativity. In fact, only three teachers out of twenty-one thought that creative students could be considered extroverts, while two of them reported their experience with introverted creative students.

On the other hand, various teachers referred to a trait which cannot be considered a personality trait, which is self-confidence. Joan argued that sometimes extrovert students seem to be more creative, though more often it is a matter of self-confidence:

'I think (..), possibly they have more self-confidence. What to say? I think generally they're more extrovert, but then some extroverts can just be, so (.), they don't think, they'll just shout a lot, and (.), and then everybody will follow'.

Half of the interviewed teachers recognized that creative students are usually self-confident, not scared of failure, and ready to take risks, as expressed clearly by Karol, '*the ones who are kind of more confident in themselves, who are more willing to take a risk and try something new. They're the ones who end up being far more creative'.*

Carter thinks that all the students can be creative, but *'they* (the students) *have to have some degree of self-confidence, in order to be able to put their opinions and creativity forward'*, though sometimes, *'they don't have the confidence to express their creativity to their peers, and* *they might show their creativity in other ways, but they don't do it verbally in group work, for example'*.

However, a certain degree of knowledge is considered necessary to be able of creating new connections (Carter, Laura, Simone and Stephan), and teachers' job is encouraging them to create these connections. Some teachers suggested that creative students are the most curious pupils (Eloise, Simone), and *'the curiosity is driving their need to branch out, find out, look out and understand the world'* (Simone). Some others think that creative pupils are those asking frequent questions (Eloise, Darren, Rachel, and Simone), *'[a] creative student is one who is able to ask questions […] about what you're being learned'* (Darren), and have many interests (Alan, Carter, and Jamie): *'I think it's someone* (the creative student) *who has, I would say, widen varied interests'* (Jamie). Jamie pointed out that creative students are not necessarily the *'traditional three science person and math'*, but the ones who have an *'appreciation and knowledge of the world where we actually live in'*, as it is this comprehensive knowledge that makes a person creative.

Three teachers evaluated a student creative if able to *'think outside of the box'* (Anya, Arthur and Eloise), that means being able *'to take an idea and to take it in a direction where I'm not even expecting it to go'* (Arthur).

4.3 What are teacher perceptions of CfE's expectations around creativity across the curriculum, and how do these expectations relate to the daily classroom practices of science teachers?

The data gathered highlighted teachers' requirement of having a curriculum which allows more freedom and flexibility and characterized by a reasonable number of topics to be delivered (section **4.3.1**). In fact, this would offer them the chance of respecting pupils learning pace and deepening topics considering interdisciplinarity and pupils' interests. The finding reported in the following section thus provides an answer to the second research question looking at the ways teachers try to implement creativity and at CfE discontinuities in supporting it.

4.3.1 The different curriculum stages support creativity discontinuously.

4.3.1.1 Varying level of curriculum flexibility

All of the teachers agreed that having a flexible curriculum does result in a higher degree of freedom in terms of teaching approaches and therefore can increase the chance of delivering a creative lesson. Having the freedom to teach means having the decision-making power on how and in which order delivering the discipline's contents. CfE, for example, is generally considered a quite flexible curriculum in terms of how to deliver the requested topics in each subject, though most of the teachers perceive it as too prescriptive during the senior phase of the school path, that is from the fourth to the sixth year of the secondary school. This perception is not linked directly to a specific CfE requirement in terms of teaching methodology, but to the number of topics that need to be delivered in preparation for the National assessments. An example of this is, Jamie, a Chemistry teacher working in a very deprived area in Glasgow (both teacher's perception and SIMD score were 1 for this interviewee), talking about CfE flexibility shared a common thought among the other interviewees:

'CfE definitely provides teachers with more flexibility, but with that flexibility, I think come constraints ironically, because you are under pressure to cover as many of the experiences and outcomes that you can […] you don't have that flexibility when it comes to fourth, fifth, and sixth year that's the skill window for the National 5, the Highers and Advanced Highers'.

Thirteen teachers recognize the freedom in teaching allowed by the CfE, in terms of when and how to develop the topics of their subjects. However, this freedom results to be just apparent as the number of contents that has to be covered does not allow to deepen them or, even worse, not to leave any pupil behind. Arthur, a Physics teacher in a rural and deprived area in Scotland, expressed it loud and clear with his words:

'It gives you a lot of freedom within your teaching, but you can't kind of, you haven't got time to veer off topic if something interesting comes up to you […] It gives you the freedom to get to those points but again you are so restricted timewise, you're not always given that opportunity for everybody to fully get there'.

CfE flexibility also allows teachers to use their preferred approach to assess their students (Education Scotland, 2019b, 2022b). However, this freedom is perceived by teachers as applicable only in the Broad General Education (BGE) phase, which is the period covering the first, second, and third year in the Scottish secondary schools (Education Scotland, 2022a). For instance, Timothy, a Biology teacher at a secondary school in the South-East of Glasgow, highlights the main difference between assessing students during the BGE phase and the following years:

'We definitely have got that flexibility within the BGE, and because you can obviously set your own assessments as well. You can, I mean, you can use a whole, whole range of materials. You can do 'design a comic strip' to 'interpretive dance', if you want to, there isn't anything you could ask, so many different ways to obviously display a task'.

On the other hand, when students start the preparation for the National assessments, planning and delivering an engaging lesson respecting students' pace, interests, and background becomes more than challenging:

'[…] when you get into your Nationals, and Highers, you can't teach relative to a pupil. You can do different types of, kind of questions and things, but at the end of the day, they need to learn how to answer (an) *exam, they need to know how* (according to the) *set* (and) *strict* (marking) *criteria for questions, what's going to get it what's not'* (Timothy).

In this regard, National assessments are commonly recognised by teachers and students as a source of stress, anxiety, and pressure, regardless of whether their evaluation reflects (or not) the students' learning. Simone's analysis, who is a former

Biology teacher and currently headteacher of an advantaged secondary school in Edinburgh (SIMD value: 7), who stated to recognise this pressure, while not being affected by it. She articulates a quite detailed analysis defining *'top-down pressure'* coming *'from […] industry, university, FE colleges, Advanced Higher, Higher, 5, 4, 3 down that way'*, or:

'That's how I see the kind of top-down pressure […] So, you then have this pressure underneath […] the universities then put pressure on the schools to say, 'we need young people who can do this and this to get into the Uni', right, and then you can't get into Uni without having done Highers. So, when you're in S3, your choices and how the curriculum is structured in school already are being dictated to, by what's needed for Higher, what's needed for National 5, what's needed for National 4'.

Two third of the teachers in this study argued that there is no time for developing a creative teaching approach due to the pressure imposed by the National assessments, like Karol, a young Chemistry teacher who stated: *'One lesson ends up being creative, but […] you don't have the time to do it for all of them'.*
Notably, the pressure experienced seems to affect all the schools regardless of their deprivation rate. In this regard, Sandra, who teaches Physics in an affluent school in Edinburgh, is quite explicit about her feelings:

'*I felt, like I couldn't take a week and go off, and teach something slightly different […] I feel pressure, because there's so much content. So, you have to, you have to go really fast. […] and you can't stop and say, 'hey, let's go into that a little bit more'. Like, 'let's, let me show you something cool' or, 'let's see go off on a tangent'. You have to just say, okay, memorize that, and then move on to the next thing'.*

Due to this lack of time, many schools in Scotland decide to anticipate the preparation for the National assessments to the third year of the secondary school, which should be dedicated to general education and to subjects that the students did not have the possibility to explore more in-depth in the first two years, according to Simone:

'You've got schools in Scotland starting their National 3 courses in S2. So, effectively, that students getting a Broad General Education up to the first year, up to 11, and then, after that, it's just a pipeline to further and Higher and that seems to be the problem'.

Consequently, this also forces the teachers to cover topics during the first and second year that were scheduled to be taught during the third year, in order to give students the chance to know a subject in advance.
This phenomenon impacts pupils' education but it also represents a source of stress and frustration for teachers for whom increasing the chances of success at the National assessments becomes more important than attempting creative teaching, as explained by Jacob, a Chemistry teacher working in a school situated in a deprived area of Scotland (SIMD value: 6):

'The time pressure that's imposed by the assignment, cuts that (creativity) *down, and therefore, it puts pressure on teachers to do a good job'.*

Or worse, the teachers themselves are aware that all this pressure might result in leaving some students behind, as clearly expressed by Arthur who stated that *'[…] you are so restricted timewise you're not always given that opportunity for everybody to fully get there'.*
Performativity pressure is felt as a major barrier to implementing other, non-assessed outcomes, such as creativity. In this regard, Jerome, who teach Chemistry in a mostly deprived area (SIMD value: 5), states:

'Everything is focused on the exams; everything is related to the success in the exams. And that's understandable. So, if you've got the chance to start kids off on it a year earlier, I suppose I can see why people do that. But it's, you know, you're limited to what you can do. […] if teachers, and I

think probably kids and probably parents as well, their main priority is to get the qualifications. So, they start them earlier'.

4.3.1.2 Performativity pressure impedes creative teaching

The lack of resources and time, and the pressure experiences by teachers, take the shape of performativity effect (see **section 2.7.1**). Lack of time has been widely described by the teachers who participated in this study, as affecting the delivery of a creative lesson, which is perceived as being time demanding to such an extent that many teachers believe that it is not possible to deliver all the contents of a subject in a creative way.

Louise remarked that helping students to enhance their creative skills is only allowed during BGE, as the increasing number of topics in the Senior phase doesn't give much time to it *'because of the sheer amount of content they need to get through'*. *'Creativity takes time'* said Sandra, because *'in order to explore things, you have to have the time to do so'*. In fact, particularly higher courses need to *'be very much content focused, rather than experiment or activity focused'* (Laila). The frustration is clear in Anya's words when she mentioned her concern on students losing their capability of analytical thought:

'In the Senior Phase, we just don't have time […] And I think pupils do start, start to lose a little bit of their like individual thought almost these days, going into Senior Phase, because they're just studying the knowledge, all the time'.

Still referring to the Senior phase Anya added that there is:

'A big, big pressure in terms of delivering in the course content and the space of time that we have. Especially in the higher courses […] and if you want to do lots of experiments and things, there's not enough time to deliver it. It has very much content focused, rather than experiment or activity focused'.

Jamie remarked that the time lack affects the possibility of *'interdisciplinary learning and working in cross-curricular'*. Kathy recognised time and, at a certain extent, money lack too as the *'biggest barriers'* in helping students enhancing their creative skills to an extent that she resorted to the help of SSERC (Scottish Schools Education Research Centre):

'The biggest help I've had with that is SSERC […] who do a lot of safety work for science teachers, but they've run these amazing training courses, where they deliberately come up with creative experiments that are cheap, and easy to do. And I find it a real struggle to get resources like that anywhere else'.

Joan added that the impossibility of covering all the contents of a course to get the students ready for the exam is clearly a problem as *'if you happen to have done the topics that they have picked, the kids are going to have done better, than if you've not done those topics'*. She also believes that the system is not *'testing the right things'*, and she thinks it would be better to use *'a more of a school-based test'* if *'forced to do a National test'*, *'I would like to see skills tested, problem solving, thinking skills analysing, rather than content, which can be accessed via the Internet'*

Jacob would prefer a system more like the university's one, where students' exams consist in writing an essay, where they must demonstrate their skills in getting all the information needed: *'Here's a topic and we'd like you to go and find out a little bit about it and write us an essay'*. However, he recognised that this kind of assessment would require a different marking system: *'You have to have 10 points for something like that, rather than just say, 'good, medium, and not so good', or nothing'*.

Five teachers out of twenty-one highlighted that within the National assessments, the National 4 which is the only exam written by the class teachers is not even considered a proper exam. The National 4 is a proper pass for students willing to leave school or going to the colleges, however it is not considered in the same way of the other exams: *'The biggest issue is for National 4 pupils, for pupils who are doing National 4, there is no exam. And so, most of them are very demotivated'* (Laureen).

Carter shared some considerations on the National 4's evaluation system:

'You can pass a National 4, because it's not graded. You can pass it with a very wide range of ability. So, some of, some of our children will scrape through in Nat 4, where others will fly through Nat 4, and do it really, really well, but they get the same thing at the end'.

Therefore, in his school it was decided to separate the National 4 students from the National 5 ones:

'We teach National 4 as a standalone course. They're not in the same room as National 5 students. We don't have bi-level National 4 and 5 in science here. […] they will focus through the course of this year on getting their National 4, obviously, but also, on building their core skills' (Carter).

Lack of resources does not help to consider students in a more holistic way as mentioned by Darren: *'It's easy enough for people, you know, within Education Scotland, or whatever, to come up with these really really good statements, worthwhile, meaningful statements, but without actually providing you with the time and the resources with which you do that'.*

Jamie highlighted that *'largely comes down to a lack of resources, when it comes to doing practical work'*, and when CfE asks teachers to enhance students' creative skills *'resources in school is certainly something about it'*. This opinion is shared by Karol, who finds difficult fulfilling this requirement, as '*the biggest barriers to that are time and money*', and commenting on my working definition of creative lesson, she added: *'But often it takes so much time and resources, that one lesson ends up being creative, but far less are in overall, because you don't have the time to do it for all of them'.*

The following table (**Table 4.7**) shows how many teachers within the interviewed ones perceived a pressure connected to lack of resources, National assessments, or more in general CfE. The years of teaching experience and the school areas' environment were added to the table to evaluate the relation between those two parameters and teachers' perceptions. In fact, the data gathered and reported in the table show no relation between teachers' length of teaching experience and teaching catchment area and their evaluations on time lack or pressure coming from CfE or National assessments.

Table 4.7. Teachers' perception of lack of resources, and pressure related to CfE and National assessments

Teacher's name (Pseudonym)	Teaching experience	School's area	Time lack	Lack of Resource(s) (Space, money)	Pressure (from CfE)	Pressure related to National assessments
1. Rachel (S)	30 years	Deprived				
2. Laura (B)	20 years	Deprived			✓	✓
3. Timothy (B)	5 years	Mixed				
4. Eloise (B)	14 years	Deprived	✓			✓
5. Darren (B)	17 years	Affluent	✓	✓	✓	✓
6. Simone (B)	6.5 years	Affluent				✓
7. Mark (B)	10 years	Affluent				✓
8. Laureen (C)	13 years	Mixed	✓		✓	✓
9. Jamie (C)	3 years	Very deprived	✓	✓	✓	✓
10. Laila (C)	4 years	Deprived	✓			✓
11. Anya (C)	2 years	Deprived	✓		✓	✓
12. Karol (C)	1 year	Mixed/ mostly deprived	✓	✓	✓	✓
13. Jerome (C)	34 years	Mixed/ mostly deprived			✓	✓
14. Jacob (C)	32 years	Very deprived	✓		✓	✓
15. Alan (C)	14 years	Mixed	✓		✓	
16. Carter (P)	14 years	Mixed			✓	✓
17. Joan (P)	32 years	Mixed	✓			
18. Sandra (P)	13 years	Very Affluent	✓		✓	✓
19. Arthur (P)	5 years	Very deprived	✓		✓	✓
20. Harriet (P)	4 years	Mixed/ mostly deprived				✓
21. Stephan (P)	35 years	Mixed				✓
Total			12	3	12	17
Proportion			0.57 (12/21)	0.14 (3/21)	0.57 (12/21)	0.81 (17/21)

(S) Science teachers/ (B): Biology teachers/ (C): Chemistry teachers/ (P): Physics teachers

Twelve teachers clearly expressed their perception of time lack as affecting the possibility of delivering creative teaching. On the other hand, a very small minority of teachers, only two of them, recognised the role of resources in facilitating creativity, such as money and space, in creative teaching. Even if it was expected that only teachers working areas with low SIMD were going to claim for those resources, Darren's case deserves a mention. In fact, he experienced teaching in low SIMD areas and even if now is teaching in an affluent school, comparing his own past experiences he recognised the importance of those two resources.

Notably, the lack of resources such as space and money results in a vicious circle which can impact teaching for a long time (Shapira & Priestley, 2020; Townsend, 1987). In fact, schools settled in the most deprived areas quite often rank at the bottom of the school ranking table as measured by the Scottish Government (Scottish Government, 2020, 2022; SQA, 2020a, 2020b), which implies more difficult access to funds that could improve for example laboratory or class supplies, common spaces, or a better-stocked library.

4.3.1.3 The role of CfE in promoting creativity

CfE expects teachers to teach in a way that would enhance students' creative skills, as it recognizes the role of creativity in terms of originality and usefulness, though it does not give any advice on how to achieve this task (see **Table 4.3**). In fact, CfE does not give any indication on how to deliver the prescribed knowledge, but gives teachers flexibility in terms of teaching approach, order of the topics to be taught and assessment procedures (Education Scotland, 2017, 2019a, 2019d), with such degree of freedom being undeniably a plus in a creative process.

Creativity is recognised as a valuable skill by CfE and deserves to be boosted, particularly in the science curriculum: *'[…] (CfE) recognised the role of creativity and inventiveness in the development of the sciences'* (Education Scotland, 2019a).

However, teachers in this study perceive this flexibility only in the BGE phase. In fact, in the Senior phase the pressure to prepare the students for the National assessments drives teachers to rely on more traditional teaching and assessing methods, based on delivering content and assessing memorised concepts, formulas, and theories. The result is a clear discrepancy between BGE assessing freedom and National assessments, that is between an assessing method based on students' skills and aptitudes and a traditional one. Performativity pressure hinders creative teaching and accordingly creative thinking development in students reducing the teachers to working in a creative way and consider students holistically only during the BGE phase or eventually once students have sorted out their National assessments:

'I think the only time they can consider the holistic thing, maybe, is when they get to S6, when maybe they have 5 good Highers, and they get good results to get university, and then in the sixth year they can get the work experience and do Community work' (Alan)

It is crucial to emphasise that seventeen out of the twenty-one teachers I interviewed regretted that, due to National assessments, the Senior phase that is supposed to start officially in the fourth year, but instead starts in the third, in some schools even in the second year (see **Table 4.7**). This procedure is decided independently by each school and ends up taking away a year of the BGE from the students. Therefore, part of BGE curriculum which is supposed to help students in developing hard and soft skills, giving them the chance of enhancing their creative thinking (Education Scotland, 2022a) is set aside for the 'greater' purpose of preparing students for the assessments: *'I think some of the BGE stuff has been pushed aside to just start teaching to the test for the exams, that you cannot avoid to think it's quite sad'*. (Joan)

There is a discrepancy between the BGE phase's requests *versus* Senior ones and frustration mixed with powerlessness as reported by Timothy:

'I do think it's a lot of that jump from the BGE to the Nationals, and the sudden change in expectation, if you're failing, you're failing. You do everything you can to help someone, but unless they get across that line and achieve it, there's not much more you can really do for them within your subject'.

4.4 What teaching approaches do science teachers report using to incorporate creativity into their lesson?

The following findings (see sections **4.4.1** and **4.4.2**) provided an answer to these research questions showing which form creativity takes when translated to the school routine.

4.4.1 The routine practice of science teaching shows teachers striving to include creativity in their lessons.

Creative science teaching and learning might be influenced by many factors, in fact when we turn to everyday classroom routine, the interviewed teachers highlighted the difficulties they meet in developing topics in a creative way. The reasons for this choice might be practical, led by a perception of time lack but can also be induced by their personal view on creativity. For example, the data gathered (see **Table 4.6**) show that only one teacher (Timothy) out of twenty-one recognised all the four characteristics of creativity (novelty, originality, usefulness, and meaningfulness), this result suggest a lack of knowledge or a difficulty in using all of them in their teaching. In fact, it is good to remember that no course meant to educate teachers to creative teaching and creativity enhancement are organised during the PGDE path the teachers. More generally, the choice to participate to courses on creativity and creative teaching are left to teachers' time availability and good will. Referring to the characteristics of creativity, I analysed which characteristics a lesson should have to be considered creative and what defines teaching creative to evaluate teachers' approach to creativity in science lessons. Interviewing teachers and gaining access to their lesson plans, where these were available, helped me to achieve this task, although I found that only a few of the interviewed teachers made use of a lesson plan. While this made my analysis more cumbersome the few provided lesson plans gave me some interesting insight into how a teaching approach can be creative.

4.4.1.1 Teachers' validation of a working definition of a creative (science) lesson

My working definition of creative lesson requires a teacher to be *'able to engage the students in developing their understanding of the subject under study in a novel way, commonly by exploiting interdisciplinary connections or using topics that are meaningful to students' lived experience'* (see section **2.7.2.1**).

I wrote this definition with the aim of being widely applicable, namely, to be applied to all subject areas, however despite of my intentions there are no evidence of it, since it was evaluated only by secondary school science teachers. Since it was formulated after conducting the first interview, I included it in the interviews of the remaining 20 teachers and asked them to share their thoughts. To avoid bias, I did not reveal the authorship of the definition until they expressed their opinion to avoid any kind of influence. Overall, most of the interviewees validated this definition and the results are summarised in **Table 4.8**, some criticism was also expressed, which will be discussed in **section 5.5.1**. In the table, part of the answers referring directly to the working definition of creative lesson are highlighted.

Table 4.8. Teachers' opinion on my working definition of a creative lesson (part 1/2)

Teacher's name (Pseudonym)	Opinion on my definition of creative lesson	Comments
1. Rachel (S)	Incomplete	*'As long as that was one example of a lesson being creative, rather than the total definition that is an example of creativity […] I think there could be other ways that teachers could be creative, and that, 'the lesson is creative if a teacher is able to engage students in developing their understanding of the subject under study in a novel way' (..), yeah, definitely, but it could be that the students are engaging each other by asking questions, you know. It could be (..), 'interdisciplinary connections' is good, but again that, 'meaningful to the students lived experience' is really important. […] it's a good statement, strong, but I don't think, I don't think it necessarily means that the lesson isn't creative if it doesn't fit in there'.*
2. Laura (B)	Positive	*'It's kind of I agree with that, that it's about me coming up with tasks, that helps their understanding of something. Yes. That's one of the things that we find really challenging at the moment, is to link the things that we have to teach with the students lived experience. […] But I do like the idea of them developing an understanding. And I do think it's important to link subjects together as well, and link skills that they're using in different subjects'.*
3. Timothy (B)	Positive	*'It kind of go on with what I'm saying in the sense of using different mediums, which is kind of you're making it relative to interdisciplinary'.*
4. Eloise (B)	Positive	*'Yeah. One hundred percent. […] Absolutely. I love the idea that it's novel. And I love the interdisciplinary connections'.*
5. Darren (B)	Positive	*'So, I would agree with that. I mean, like I said before, maybe I didn't have it under the creativity umbrella, but certainly, getting the kids to see the relevance to real life is important. And interdisciplinary […] We don't do enough of that, I agree. And I think that I can tell you that I can see that as being part of creativity. Absolutely. Yeah'.*
6. Simone (B)	Negative	*'I wouldn't say that's great. If that wouldn't come into my definition of creativity. […] so, 'a lesson is creative, if the teacher is able to engage the students in developing their understanding of the subject under study in a new way', right? So, if you just left it like that, would that make the lesson creative? No, it wouldn't, right? Because […] you've just taken a new way of showing the children, developing their understanding of the subject, in a new way. […] You've got to take your knowledge of the curriculum, your knowledge of young people, your rights respecting curriculum, your inclusive curriculum, your anti-racist education curriculum, and design an experience for those young people. And that's your creative output, is the design of those experiences for young people, based on all of these other disparate parts that you bring together, and offer out to the young people'.*
7. Mark (B)	Incomplete	*'To an extent, I do agree. And I would say that that is a creative type of lesson, but creativity as a skill is more intangible than that. So, I'd be thinking, ahem, that the definition that you've given is, if I was observing a student teacher, I would be saying, 'that is a really creative lesson, and well done'. I'm not sure that that necessarily defines creativity as a skill'.*
8. Laureen (C)	-	-
9. Jamie (C)	Positive	*'I'm trying to develop their understanding of the subject under study in a novel way […] is fundamental to creative teaching and learning. […] I've mentioned previously, the interdisciplinary connections and […] the most used part is using, trying to use versatile techniques and terms of what's in use of the novel approaches, and using topics that are meaningful to students' lived experiences. […] But I would say that certainly that approaching things in the study in a novel way, and really take the topic to the real world is certainly what I try to do in my teaching'.*

(S) Science teachers/ (B): Biology teachers/ (C): Chemistry teachers/ (P): Physics teachers

Table 4.8. Teachers' opinion on my working definition of a creative lesson (part 2/2)

Teacher's name (Pseudonym)	Opinion on my definition of creative lesson	Comments
10. Laila (C)	Positive	*'That's exactly what I was thinking creative lesson is, especially the fact that you've talked about a novel way. […] it's really nice definition, and that kind of covers all different things rather than just, you know, creativity'.*
11. Anya (C)	Positive	*'Oh, okay that's pretty much what I said. […] if you come up with something that's new, and fresh, and something they've never seen before, they do tend to engage more, because it's not just monotonous, the same thing every day. […] I kind don't do it in every lesson, and because we're tight of time sometimes. […] Trying to relate back to kind of real life and real things that happen, definitely'.*
12. Karol (C)	Positive	*'I'd agree in sort of the novel way, a way that they've not really considered before. Or using topics that are meaningful to their lives, absolutely'.*
13. Jerome (C)	Positive	*'There are degrees of interdisciplinary learning, […] I think what you're talking about is a broader version, where you're encouraging the kids to bring something of themselves into the lesson. And I think that's a, that's a true interdisciplinary'.*
14. Jacob (C)	Positive	*'That definition is […] it allows, allows for creative planning, but it allows creativity within the lesson on a spontaneous way'*
15. Alan (C)	Positive	*'Yeah, I'd agree with that. […] I think good teachers are almost creative in every lesson. I think about teachers, very good teachers are creative every lesson that you do. Some are very charismatic and will just talk, give a lesson or like engage with pupils and ask lots of questions. Some will be very careful on the board start writing a concept and expanding and doing the diagrams and labelling it and telling jokes and stories. You know, in a way a lesson is a very creative thing. You're creating your interpretation'.*
16. Carter (P)	Positive	*'It's about then drawing from multiple places, drawing information and skills from multiple places to try and learn something new, trying to engage with a new topic'.*
17. Joan (P)	Positive	*'I think that's what Curriculum Excellence, for Excellence was meant to be. […] But I think that's not what's happening, because those exams aren't designed like that. Their exams aren't interdisciplinary correlations'.*
18. Sandra (P)	Positive	*'Yeah, interdisciplinary connections, for sure. And meaning meaningful to students lives. Yeah'.*
19. Arthur (P)	Positive	*He made an example of application of a topic related to students lived experience.*
20. Harriet (P)	Fairly positive	*'Yes, that would be good, as I'm not completely sure I understand what it is. […] I don't think I always manage to deal with the students' lived experience. I don't think I would have linked that to creativity. I think I would more go about a novel way, or something that was slightly different, for me. […] I think is a really good definition though, because I think when you do build those relationships with pupils like that last part, so, 'using topics that are meaningful to them', I think that those become easier'.*
21. Stephan (P)	Positive with limits	*'Okay. Yeah, but I think, you know, as I said before, you know, it's when something's done in a new novel way, […] I would say so a need, a need of an interdisciplinary connection, but obviously, I think that often new developments and all sorts of things happen at the boundaries of disciplines. So there, obviously, can be an interdisciplinary aspect of lots of elements of creativity'.*

(S) Science teachers/ (B): Biology teachers/ (C): Chemistry teachers/ (P): Physics teachers

Teachers who agreed with all the characteristics of a creative lesson reported in the definition, compared it to their teaching approach and highlighted their attempts of planning a lesson that is meant to engage students through interdisciplinary contents and developing connections with students' lived experiences. For example, Anya recognised her approach to teaching in the definition, especially related to students lived experience, however she cannot refrain from comment on the lack of time she perceives affecting her possibility of delivering a creative lesson. Similarly, Joan appreciated the definition, but cannot avoid highlighting that this approach to school lesson was the one supposed to be supported by CfE, *'that's what Curriculum Excellence for Excellence was meant to be'* [...] *that's not what's happening'*. She made a step forward while interpretating the definition, as she looked at the final step, that is the approach to the assessments, and specifically the National assessments, *'[...] because those exams aren't designed like that. In their exams there aren't interdisciplinary correlations'*.

Some teachers highlighted a connection between *engagement* and *students' experiences*, which was interpreted as delivering a lesson where roles are no more strictly defined but students are active members:

'There are degrees of interdisciplinary learning, [...] I think what you're talking about is a broader version, where you're encouraging, encouraging the kids to bring something of themselves into the lesson. And I think that's a, that's a true interdisciplinary (lesson)' (Jerome).

I detected evidence of the desire of creating something that goes beyond the concepts of novel and original, but striving for a fresher and *'spontaneous'* environment, *'that definition is [...] it allows, allows for creative planning, but it allows creativity within the lesson on a spontaneous way'* (Jacob).
Alan emphasized the teacher's role in terms of performance or charisma, which results in a traditional chalk-and-talk lesson becoming something personal and creative due to teacher's personality,

'I think about teachers, very good teachers are creative every lesson they do. Some are very charismatic and will just talk, give a lesson or like engage with pupils' questions. Some will be very careful on the board start writing a concept and expanding and doing the diagrams and labelling it and telling jokes and stories. You know, in a way a lesson is a very creative thing. You're creating your interpretation'.

Creativity in teaching is difficult to achieve and the definition itself I refer to implies that teachers plan their lessons thinking about how to link the topics to students' lived experience, and this means having an in-depth knowledge of students, which is going to be *'challenging'* as highlighted by Laura,

'One of the things that we find really challenging at the moment is to link the things that we have to teach the students' lived experience'.

On the other hand, Harriet, who gave a fairly positive evaluation of my definition, identifying in the word *novel* the essence of creativity, and defining it as '*something that was slightly different'*. However, she does not think that a creative lesson can be delivered recurring to connections to students' lived experiences, although she believes that these connections associated with *'topics that are meaningful to them'* might help in building *'relationships with pupils'* which can make easier to engage students in the lesson,

'I don't think I always manage to deal with the students' lived experience. […] I would more go about a novel way, or something that was slightly different, for me […] when you do build those relationships with pupils like that last part, so 'using topics that are meaningful to them', I think that those become easier'.

Laura supports the idea that an interdisciplinary approach could help students to develop an in-depth understanding of the subject by looking at different subjects' topics as interconnected, *'The idea of them developing an understanding […] it's important to, to link subjects together as well, and link skills that they're using in different subjects. And we've tried to do that in with our new first year science course this year to show that skills that they're learning across subjects are something that they can use within science, which can help them improve"* (Laura).

Two teachers found the definition partially incomplete, perceiving it as describing just examples of a creative lesson. Rachel argued that the contribution of the students in the lesson is fundamental as they can engage '*each other by asking questions'*. Furthermore, having the freedom to ask questions to each other or to the teacher allows to look at the topic from different perspectives,

'I think there could be other ways that teachers could be creative, and that 'the lesson is creative if a teacher is able to engage students in developing their understanding of the subject under study in a novel way', yeah, definitely, but it could be that the students are engaging each other by asking questions, you know' (Rachel).

Mark imagined to be observing a student teacher's lesson and referring the definition to this hypothetical situation, he said that he would have evaluated it creative. However, looking for creativity in the definition, he could not recognise it, as he considers it a far too *'intangible'* concept to be constrained in the limits of a definition, and because of that difficult to be defined: *'To an extent, I do agree. And I would say that that is a creative type of lesson, but creativity as a skill is more intangible than that'* (Mark). In fact, further on during the interview he added: *'How can you ensure a standard for creativity? If you can measure it'*.

The definition received just one negative response, from Simone, who teaches Biology in an affluent school in Edinburgh, who commented that:

'I wouldn't say that's great, that wouldn't come into my definition of creativity. […] so, 'a lesson is creative, if the teacher is able to engage the students in developing their understanding of the subject under study in a new way', right? So, if you just left it like that, would that make the lesson creative? No, it wouldn't, right? Because if you just take it on that bit there, right? Because what you've done is, you've just taken a new way of showing the children, developing their understanding of the subject, in a new way. […] You've got to take your knowledge of the curriculum, your knowledge of young people, your rights respecting curriculum, your inclusive curriculum, your anti-racist education curriculum, and design an experience for those young people. And that's your creative output, is the design of those experiences for young people, based on all of these other disparate parts that you bring together, and offer out to the young people'.

Basically, in her opinion, only this comprehensive and in-depth knowledge allows teachers to *'design an experience for those young people'* that is going to produce a truly *'creative output'*.

Referring to the working definition a creative lesson, its characteristics are novelty and teaching approaches which focus on interdisciplinary connections and topics meaningful to students lived experience. The data gathered allowed then to summarise teachers' opinion on these characteristics in **Table 4.9**.

Table 4.9. Analysis of teachers' opinion on creative lesson's key features

Teacher's name (Pseudonym)	Key features		
	Novelty	Interdisciplinary connections	Topics meaningful to students' lived experience
1. Rachel (S)	✓	✓	✓
2. Laura (B)	✓	✓	✓
3. Timothy (B)	✓	✓	✓
4. Eloise (B)	✓	✓	✓
5. Darren (B)	✓	✓	✓
6. Simone (B)	✓		✓
7. Mark (B)	✓	✓	✓
8. Laureen (C)	✓		✓
9. Jamie (C)	✓	✓	✓
10. Laila (C)	✓		✓
11. Anya (C)	✓	✓	✓
12. Karol (C)	✓		✓
13. Jerome (C)	✓		✓
14. Jacob (C)	✓		
15. Alan (C)	✓	✓	
16. Carter (P)	✓	✓	✓
17. Joan (P)	✓	✓	✓
18. Sandra (P)	✓	✓	✓
19. Arthur (P)	✓		✓
20. Harriet (P)	✓		✓
21. Stephan (P)	✓		✓
Total	21	12	19
Proportion	1 (21/21)	0.57 (12/21)	0.90 (19/21)

(S) Science teachers/ (B): Biology teachers/ (C): Chemistry teachers/ (P): Physics teachers

4.4.1.2 Some elements of creativity are lost when science is presented for educational purposes.

Teachers' perception of CfE requirements joined with the performativity effect explored in Section 4.3 result in a discrepancy between teachers' ideas of creativity and creative lesson and what they manage to hold while delivering a science lesson. The science curriculum is perceived as too wide to be deepened, hence several topics are briefly examined.

As mentioned by Arthur,

'You haven't got time to veer off topic if something interesting comes up to you, because you've got to be focused in on those things and, because those are expected, and those are kind of like benchmarks for kids, you know, they need to know this thing to know that […] you are so restricted timewise'.

As a result, he recognises that this approach confines *'the creative side'* to be *'side-tracked'*. Similarly, Harriet is aware that every pupil *'has to achieve as many of the outcomes as possible'*, as *'they all have to have a similar experience'*, but *'you don't really get to do well. I'm going to take a little bit less topic and a little bit of that, and I'm going to put together, and it's going to be that fab-holistic formatively assess thing, but I don't think we do get that'.*

Besides, the assumed teacher's autonomy in delivering a topic is simply not realistic, or at least not what is happening in the schools, *'you don't really have the autonomy to be able to do that in your own classroom. You do as a school or as a department to be able to decide how you deliver it, and how you meet it'* (Harriet).

In teachers' opinion, the chance to assess the various topics in different ways allowing students to express their creativity in the delivery of the topic under study is restricted to the BGE phase, *'we can do projects, and then we can do debates. We do a lot of group work. We do a lot of experiments'* (Laila).

Or as remarked by Laureen, *'in BGE, we are encouraged as much as possible to use a variety of assessments. So, they could do an assessment through a presentation or report, or they can make a video, they can make a cartoon strip, things like that, and which is great for engagement'.*

Harriet, for example, assessed the work on friction of a girl who showed her how a 10p coin slides on different surfaces, *'so, she was outside, and she was on the grass, she was on our driveway, our windowsill, a carpet, a table […] she made different parachutes, and opened that in the conservatory, and then said, 'Well, rather than write up, can I take pictures? or do a video?'.* Another example reported by her on the different and creative students' answer to a proposed assessment was the work of a pupil who built and labelled *'a model of a giant sperm cell'* with plasters and polystyrene.

With the purpose of understanding if creativity was present and encouraged during students' assessments, I asked teachers about their preference between multiple-choice and open-ended questions (*Do you prefer to pose your students open-ended problems or multiple-choice questions?*). This question allowed me to understand the context which led the teachers to use one type of question respect to the other. In parallel, they were asked which one they considered to support creative thinking (*Which questions do you think are more useful with respect to the development of creative thinking?*).
In general, the assessments' questions are mostly limited to multiple-choice questions or fill-in exercises, and wherever open-ended questions are proposed, students are usually trained to answer. My assumption, supported by literature on science teaching and learning and the effect of performativity on students (see sect. **2.6.3**, **2.6.4** and, **2.7.1**), is that giving detailed or even strict indications on how to answer to an open-ended question might affect students' creativity in their approach to the exercise.
Most of the interviewed teachers (eighteen out of twenty-one) consider open-ended questions more related to creativity with respect to the multiple-choice ones, however avoiding training students to answer them seems impossible due to the marking system adopted by CfE (see **Table 4.10**). In this regard, Joan, a Physic teacher with 32 years of teaching experience, explained me the National assessments'

marking system, which is grounded on answers based on concepts previously settled, where any diversion from them is not evaluated, and no space for creativity is left.

'So, what happens is, you have groups of teachers, who are on the examining team. And you have groups of teachers that write a paper, and then you have different people who check the paper. They normally send it to people in universities to check, as well, that there's nothing bad in there […] and then a group of teachers again on the team, they will discuss the paper and decide what is acceptable for an answer, and what isn't. And then the markers will meet together, and the examining team will tell the markers, 'this is how you have to mark this question. You can accept this, this, this, but you can't accept that'. So, it's all very prescriptive' (Joan).

Hence, for example, a student writing a ten-line long answer might get lower marks then a student writing a shorter one, even if the first did not go off topic, but simply mentioned two out of the three pre-settled concepts required.
Teaching how to answer to open-ended question is made necessary by the National assessments marking system, which however is often unclear as it is projected by external examiners.

'The marking scheme doesn't help either. It says three marks as a good answer. Two marks are a reasonable answer. But they don't actually give you a marking scheme' (Laila).

Karol shares the same opinion as Laila, and referring to National 5, stated that *'The marking scheme is basically, 'it's worth three marks, it's worth two marks, it's worth one mark' giving no description of what each one is worth'.*
Arthur being empathetic towards students' struggling to understand how they are supposed to answer open-ended questions, tries to explain them the marking system,

'And you say 'Look, here's the marking scheme'. The marking scheme just says, 'A good understanding of Physics. A moderate understanding of Physics. Some understanding or no understanding'.

Students find hard to understand the marking system, because of the width of topics questioned during the assessment, as explained by Jacob:

'I don't know if, if you read these so-called open questions, you would be hard pressed as a teacher, or as a university graduate, you would be hard pressed to know when to stop. You could, you could write a whole thesis on some of these questions'.

Alan underlines that understandably open-ended questions are *'unfamiliar'* to students, who clearly like *'predictability in the exam'*, but admits that they can *'get all three marks in one sentence'*, which is a common teachers' driving force in training them. Moreover, referring to the evaluation of diagrams and tables which have been recently introduced in Chemistry and Physics National assessment, he adds:

'There's no marking scheme for this, it's up to the examiner of the science question. Too much really up to the interpretation of the examiner, to decide whether they get one, two or three marks in most chemistry questions either right or wrong' (Alan).

A possible solution to make easier answering to open-ended questions comes from three teachers (Jamie, Joan, and Rachel), who think that students should approach open-ended questions in their first year to better coping with them by the time of the National assessments.

Jamie shares other teachers' opinion who highlighted the role of creative thinking associated with open-ended questions,

'I would say they (open-ended questions) *are probably the ones that I would go to follow if trying to encourage pupils to think in a creative way, because you're not limiting their options, you are not limiting their thoughts, so you're really leaving it open to them'.*

Even recognising that they help to get an evaluation of students' knowledge, Timothy talks about an *'assessment literacy'* problem due to the language used in National assessments' open-ended questions which makes them particularly difficult: *'The questions aren't necessary written in the most obvious means. The kids have the knowledge. If I reword the question and gave it to them, they'd get it right'*.

The teachers agree on the necessity of educate students to answer to an open-ended question to get the students ready for the National assessments. However, this implicit requirement might mean holding back students' creativity or at least set boundaries to it. On the other hand, teachers consider training students to answer assessment' questions inevitable, because of time constrain,

'Now, I always encourage my pupils to write as much as they can. However, we need to keep it in their mind, there's a time constraint and an assessment. And if every answer was going on, and on, and on, and on, would that have implications for finishing the exam? […] so, I think there's got to be a balance between training them for the answer, but also encouraging them' (Eloise).

Training students to answer to open-ended questions emphasises performativity effect on teachers, further impoverishing any creative contribution to teaching. In fact, teachers perceive that it is the system itself asking to make students able to answer to those questions and not completing that duty means that they *'are failing them* (the students). *And it doesn't matter how scientific you are, how creative you are, how beautiful your creative curriculum is, right? If you don't spend time doing that, then you let them down, because that is the system by which they're going to be judged'* (Simone).

Hidden behind Simone's words, there is a strong sense of responsibility and concern for her pupils' future, but there is also the sense of failure that would arise by an eventual unsuccessful exam result of her pupils. These feelings are recognizable also in Arthur's words: *'You're not always given that opportunity for everybody to fully get there'*.

Laura is aware that helping students to trace in detail the answer expected in the National assessments means putting aside creativity but hopes they will have the chance to develop their creative skills further on eventually in university,

'they'll have more opportunities to become more creative. But, at this level, my job at National 5 is to prepare them to sit an exam and get three marks in those questions. So, within science, I probably have carved their creativity, because I want very specific answers, specific words written in a specific way, so that they get the point awarded to them' (Laura).

In general, multiple-choice questions are often used by teachers to quick check an acquired knowledge, eventually a topic that has just being explained, but can be used also to promote students' self-confidence.

'If you've just taught them something, it's sometimes good to start with a multiple-choice question, because it makes them feel more confident' (Sandra).

Jamie, for example suggests '*a creative approach to teaching'* in multiple-choice questions and Timothy explains it arguing that they can enhance students' problem-solving skills, for example if the teacher provides multiple-choice questions with very similar answers,

'It means that they (the students) *kind of need to go through, and actually work it out themselves, and […] figure out why something is wrong. And I think that's bringing out some problem-solving skills'.*

Regarding teachers' opinion on educating students to answer to open ended questions, **Table 4.10** reports their ideas about the relationship between creativity and these questions. The table shows a certain discrepancy between the nearly unanimous belief that they are connected to creative thinking and its requirement of providing detailed answering instructions.

Table 4.10. Open-ended questions and their relationship with creativity as compared to the requirement of training affecting creativity in teachers' opinion.

Teacher's name (Pseudonym)	Open-ended questions are related to creativity	Open-ended questions require training which affect creativity
1. Rachel (S)	✓	✓
2. Laura (B)	✓	✓
3. Timothy (B)	✓	✓
4. Eloise (B)	✓	✓
5. Darren (B)	✓	✓
6. Simone (B)	✓	✓
7. Mark (B)	✓	
8. Laureen (C)	✓	
9. Jamie (C)	✓	✓
10. Laila (C)		
11. Anya (C)	✓	
12. Karol (C)		
13. Jerome (C)	✓	
14. Jacob (C)		
15. Alan (C)	✓	
16. Carter (P)	✓	
17. Joan (P)	✓	✓
18. Sandra (P)	✓	
19. Arthur (P)	✓	
20. Harriet (P)	✓	
21. Stephan (P)	✓	
Total	18	8
Proportion	0.86 (18/21)	0.38 (8/21)

(S) Science teachers/ (B): Biology teachers/ (C): Chemistry teachers/ (P): Physics teachers

4.4.2 Teachers' plans for implementing creativity rely on curriculum knowledge, resources available, differentiated tests, and building up relationship with pupils.

As observed previously, the teaching experience of the interviewed teachers was quite heterogeneous. In fact, nine teachers had less than seven years of teaching experience, eleven of them had between ten and twenty years of teaching experience and five of them have been teaching for more than thirty years (**Table 4.11**).

Table 4.11. Interviewed teachers' teaching experience

Number of teachers	Years of teaching experience
9	Less than 7 years
7	Between 10 and 20 years
5	over than 30 years

In this study, teachers' idea of creativity and creative lesson is not considered dependant from the years of teaching experience. This assumption is based on the fact that teachers are not educated to creative teaching and their idea of creativity is related only to their own personal interest in developing new teaching approaches, which makes it automatically unrelated to the length of their teaching experience. However, an in-depth knowledge of CfE might advantage teachers of longer experience in planning their daily routine. For example, more experienced teachers might be advantaged with respect to less experienced ones, if the first are open to using new or modern teaching tools. On the other hand, newly teachers might have a more mechanistic approach to delivering a lesson. For example, I already mentioned Rachel, who talked about filtration using orange juice with and without bits, instead of referring to something *'very boring'* or *'completely abstract'* such as the insolubility of the lead iodide.

'Why would I do that? What am I doing that for? Whereas if you say, well, what's the difference between this orange juice? Yeah, this orange juice is with bits, this orange juice is without. They were made from concentrate? And this which is called […] diluting juice'. And, actually, on those boxes

are the words diluting, concentrate, bits no bits. So immediately you can get the concept of soluble and insoluble' (Rachel).

Rachel has thirty years teaching experience and made the perfect example of adapting the curriculum with the respect to her audience. In fact, her in-depth knowledge of the curriculum allowed her to manage the lesson time and focus on teaching students the meaning and appropriate use of significative scientific concepts, such as *'diluting'*, *'concentrate'*, or *'soluble and insoluble'*.

Darren, with seventeen years of teaching experience, provided students the essentials information on enzymes, challenged them to resolve a specific aim of an experiment finding and using the appropriate equipment available in the laboratory,

'Ok, here's the aim of experiment. There's all the material in the back of the room. Go and workout what you need, devise your experiment, and then come back to me'.

Jacob, a chemistry teacher with thirty-two years of teaching experience, approached the environmental pollution' topic referring to the plastic content of face covering, while Arthur talked about the carbon capture and the electricity used while brewing a cup of tea, because *'seven billion cups of tea drunk in the UK every year'*.

Hence, the curriculum knowledge offers teachers the chance of thinking to different and creative ways of proposing the science topics as well as being aware in the management of the lesson time.

4.4.2.1 Building up a secure relationship with pupils promotes creativity.

All the teachers participating in this study recognize the link between education and creativity, and that it is necessary to know the students more deeply in terms of their social background, interests and hobbies to be able to develop a creative lesson and thus elicit the enhancement of students' creative skills. In facts, the *'access'* to students' lives allows teachers to develop their topics connecting them to their reality. This topic frequently emerged when teachers were asked about the freedom of considering the students in a more holistic way as requested by the CfE. Eighteen out of the twenty-one interviewed teachers recognized the importance of building up a deeper relationship with the students during the senior phase, but also acknowledge the difficulty of achieving this task. Jacob expressed a strong opinion on the value of treating students in a more holistic way: *'I would say that's just my job'*.

In Jacob's words is possible to recognise his belief of the importance of knowing the students to develop a creative lesson:

'The way that we engage with the students is more personal, though I know that you can't have an individual relationship with each pupil in a class of 20, but you can know them. And because you have a knowledge of each pupil, then when you're working with the group as one, they can get a sense of you and your creativity'.

Harriet referring to the portion of the creative lesson definition that states that *'Using topics that are meaningful to them'* claims that *'without relationships creativity doesn't stand a chance'*. Building a relationship has an impact on students' self-confidence, such as the experience described by Timothy with a girl who asked him not to ask her any questions,

'It is about knowing what the barrier for their confidence is. I've got one pupil who said to me, at the start of the year, 'So, please don't ask me any questions' and now I've actually, I started to just dropping her the occasional question, but it was stuff that I know she's got in front of her, or that I knew that she would be able to, you know, simple one-word answers. And, as a result, I now will ask her for an answer or something, a contribution during most periods now'.

Knowing the students might mean expanding a topic based on their interests to enforce their engagement into the discipline, as pointed out by Harriet:

'If I know, I've got some kids who are super interested in space, so, maybe, I went 'Okay, I'm going to extend the space part of the topic a little bit' and spend a little bit less time on photosynthesis'.

Laila, a Chemistry teacher, considers the possibility of building up a relationship with students as an opportunity for developing her subject differently:
'*You really do have the opportunity to kind of relate to pupils, and kind of, you know, take what they like and do something slightly different'.*

Carter reported a lesson where he developed the topic of circular motion referring to parkour, an athletic discipline where athletes overcome *'obstacles in a man-made or natural environment through the use of running, vaulting, jumping, climbing, rolling, and other movements […] without the use of equipment'* (Bauer, 2023). Similarly, Laila who is passionate about football and boxing managed to build up a relationship with a couple of students of her class as passionate of these sport as her, that helped her to engage them more in her lessons. In particular, when she was asked how she recognises creative students her first answer was: *'[…] the first part of kind of any class is getting to know them'* to figure out their interests.
Again, Carter emphasized the necessity of sharing information about the students with colleagues:
'It's difficult to get to know the students, especially if you only see them for a few periods a week. Ahem, so it's about getting the information between teachers about what these kids do, and what their interests are, and what they're good at, what they excel at, what they enjoy, what they don't enjoy'.

The difficulty in building a relationship of knowledge and trust with students might be having the chance of spending enough time with them, which is clearly easier in small schools with respect to bigger ones, as the opportunity of meeting inside or outside of the department are bigger. From this point of view, rural areas or small town are advantaged.

4.4.2.2 Investigating relationship between students' self-confidence and creativity: self-confidence as factor affecting creativity in teachers' perception

The data gathered highlighted a relation between creativity and self-confidence. In fact, eleven teachers out of the twenty-one interviewed recognised that boosting students' self-confidence is a way to enhance their creativity.

The teachers have the chance to foster students' self-confidence through the building up of a relationship with the students, which it is recognised to have a role in stimulating their creativity.

In line with the expectations of CfE and the focus on numeracy, literacy and Health and Wellbeing, all the interviewed teachers recognised the importance of students' self-confidence for their life and well-being. They reported their effort in trying to enhance it within their teaching activities, and half of them recognise it as a personal trait of creative students. The link between self-confidence and creativity emerges from teachers' words when they define creative students as *'risk-takers'* (Laureen, Joan), *'unafraid of the criticism of their peers'* (Harriet), *'brave'* (Harriet), *'not scared to fail'* (Alan), or simply *'confident'* (Harriet, Jamie, Jerome, Karol, Rachel, Sandra, Timothy).

Karol thinks that creative students are,

'The ones who are kind of more confident in themselves, who are more willing to take a risk and try something new'.

Moreover, she takes her idea to the extreme that students who do not take risks will never be able to be creative. Alan identifies resilience as a characteristic of creative students, whose adaptability requires them to be *'not scared to fail'*, or to be criticised by their peers. This idea is shared by Harriet who claimed that creative students *'are brave, and they are normally unafraid of the criticism of their peers [...] I think it's people that are brave and willing to be given anything a try'.*

On the other hand, Carter who also believes in the importance of being confident does not exclude the possibility that creative students who do not *'have the confidence to express their creativity to their peers […] might show their creativity in other ways, but they don't do it verbally in group work'*.

Hence, he distinguishes shyness and being introvert from being self-confident, which is a sharp contrast with what reported by Simone and Mark reported. Simone believes that students' self-confidence is important, but in her opinion creative students are mostly curious and ask questions, and when asked if this attitude might be connected with them being confident, she answered overlapping it with being extrovert:

'I know lots of students who are particularly creative but aren't necessarily self-confident […] it's going to be this kind of expressively big showy way, but a quiet student who's sitting there trying to figure out some puzzle of the universe, or something, doesn't necessarily have to have a lot of self-confidence, you know, so it's not something that I particularly associate with being creative'.

Instead, Mark, who highlighted a certain degree of openness and thirst for knowledge in creative students, when I mentioned self-confidence, replied:

'I don't always have the most extroverted pupils who want to do Advanced Higher biology with me, but they are incredibly creative individuals […] They don't have to be extroverted, they don't have to be highly organized, they just have to be open'.

Joan, who want them to learn that any answer is equally important, and they should not be afraid of being wrong sometimes claimed,

'[…] what we should be teaching is getting it wrong is a life lesson. […] I try and say, 'look, science is really about a life lesson […] in science, you have an idea, you test it. And you know what, sometimes you're wrong and sometimes you're right. And it doesn't matter whether you're wrong or right, as long as you learn if it's wrong, and you go and change your idea'.

Timothy instead tries to boost students' self-confidence using differentiated assessing methods, while Eloise relies on praise, even when getting a wrong answer, both approaches resulting in giving pupils the chance of expressing their creativity.

In **Table 4.6** I reported teachers' opinions on creativity's key features with respect to their belief of enhancing students' creative skills through creative teaching, nevertheless, creative teaching might not be sufficient if it does not match with self-confidence. Nearly all of the teachers, eighteen out of twenty-one, agree that teaching creatively is going to enhance students' creative skills, but only eleven of them believes that self-confidence is the main feature of creativity.

Promoting students' self-confidence is fundamental and, in this regard, the combination of the data of **Table 4.9** with this result strengthens this finding by comparing creative lesson's key concepts with teachers' belief in teaching for creativity and the importance they give to students' self-confidence (**Table 4.12**).

Table 4.12. Creative lesson's key features, teaching for creativity and students' self-confidence in teachers' opinion.

Teacher's name (Pseudonym)	Creative lesson's key features	Engagement factors		Creative teaching resulting in teaching for creativity	Students' self-confidence related to creativity
	Novelty	Interdisciplinary connections	Topics meaningful to students' lived experience		
1. Rachel (S)	✓	✓	✓	✓	
2. Laura (B)	✓	✓	✓	✓	
3. Timothy (B)	✓	✓	✓	✓	✓
4. Eloise (B)	✓	✓	✓	✓	✓
5. Darren (B)	✓	✓	✓	✓	✓
6. Simone (B)	✓		✓	✓	
7. Mark (B)	✓	✓	✓	✓	
8. Laureen (C)	✓		✓		✓
9. Jamie (C)	✓	✓	✓	✓	✓
10. Laila (C)	✓		✓	✓	
11. Anya (C)	✓	✓	✓		
12. Karol (C)	✓		✓	✓	✓
13. Jerome (C)	✓		✓		✓
14. Jacob (C)	✓			✓	
15. Alan (C)	✓	✓		✓	✓
16. Carter (P)	✓	✓	✓	✓	✓
17. Joan (P)	✓	✓	✓	✓	✓
18. Sandra (P)	✓	✓	✓	✓	
19. Arthur (P)	✓		✓	✓	
20. Harriet (P)	✓		✓	✓	✓
21. Stephan (P)	✓		✓	✓	
Total	21	12	19	18	11
Proportion	1 (21/21)	0.57 (12/21)	0.90 (19/21)	0.86 (18/21)	0.52 (11/21)

(S) Science teachers/ (B): Biology teachers/ (C): Chemistry teachers/ (P): Physics teachers

The data highlight a consensus amongst teachers that creative teaching requires a novel approach to teaching and a holistic engagement of the students in the lesson and these two approaches to the lesson can be achieved through creative teaching. This table shows that students' self-confidence is even more crucial for eleven of the interviewed teachers, as they consider it the main characteristic of creative students. A correlation was identified between self-confidence and creativity crossing the results obtained in the study of teachers' perception of their school catchment area's deprivation (**Table 3.2**) and the importance they give to self-confidence (**Table 4.12**). In fact, a data comparison of teachers' opinions on the school environment, students' self-confidence and creative teaching offered the chance to better understand the relationship between self-confidence and creativity.
These data show that teachers working in mixed or deprived areas perceive the importance of self-confidence and their role in its development as a key to access to students' creativity (**Table 4.13**). Actually, among the eleven teachers claiming that self-confidence is the main characteristic of creative students, ten teach in what they define as deprived or mixed areas. Darren is the eleventh and currently works in a wealthy school, however, he used to work in a mixed one.

Table 4.13. Teachers' opinion on school environment, students' self-confidence and creative teaching

Teacher's name (Pseudonym)	Area served by the school (based on teachers' comments)	Creative teaching resulting in teaching for creativity	Students' self-confidence related to creativity
1. Rachel (S)	Deprived	✓	
2. Laura (B)	Deprived	✓	
3. Timothy (B)	Mixed	✓	✓
4. Eloise (B)	Deprived	✓	✓
5. Darren (B)	Affluent	✓	✓
6. Simone (B)	Affluent	✓	
7. Mark (B)	Affluent	✓	
8. Laureen (C)	Mixed		✓
9. Jamie (C)	Very deprived	✓	✓
10. Laila (C)	Deprived	✓	
11. Anya (C)	Deprived		
12. Karol (C)	Mixed/ mostly deprived	✓	✓
13. Jerome (C)	Mixed/ mostly deprived		✓
14. Jacob (C)	Very deprived	✓	
15. Alan (C)	Mixed	✓	✓
16. Carter (P)	Mixed	✓	✓
17. Joan (P)	Mixed	✓	✓
18. Sandra (P)	Very wealthy	✓	
19. Arthur (P)	Very deprived	✓	
20. Harriet (P)	Mixed/ mostly deprived	✓	✓
21. Stephan (P)	Mixed	✓	
Total		18	11
Proportion		0.86 (18/21)	0.52 (11/21)

(S) Science teachers/ (B): Biology teachers/ (C): Chemistry teachers/ (P): Physics teachers

4.5 Summary of findings

This chapter described the interviewed teachers' thoughts on creativity, creative teaching, and creative students. An in-depth analysis of the impact of the CfE on time management, pressure connected to upcoming National assessments, and frustration for not giving students a comprehensive learning experience, also known as the *performativity effect* (Ball, 2003; Clarke, 2013; Locke, 2015) was considered in the analysis. The performativity effect was not something the interviewees were asked about directly, rather it emerged spontaneously and was broadly reported among them. A very high percentage of teachers, seventeen out of twenty-one, experienced a sense of pressure connected to teaching students with the only purpose of preparing them for the National assessments, and more than half of them talked about time lack and pressure due to CfE (see **Table 4.7**). The literature study and the data gathered allowed me to develop an in-depth analysis of the working definition of creative lesson, and the proposed concepts of *novelty*, *originality* and *engagement* have been confirmed by the teachers' view on creativity. Furthermore, eleven interviewees highlighted the importance of students' self-confidence as a prerequisite to develop their creativity, and on the other hand (see **Table 4.12**). Self-confidence and creativity, in general, emerged to be linked to some extent to the social background, and a discrepancy was observed between teachers' perception of the school population's social and economic background and the SIMD value of the corresponding school area. These discrepancies were analysed through Spearman's rank-order correlation coefficient, and the data were crossed with teachers' opinions on the relation between self-confidence and creativity which appeared stronger for students coming from a deprived or mixed background (**Table 4.13**). Self-confidence, together with novelty and engagement have been isolated as considered the major contributing factors to creative teaching and teaching for creativity.

Chapter 5. Discussion of data and findings

5.1 Introduction

The findings derived from the data reported in **Chapter 4** will lead the development of this discussion chapter, which supported by literature, will provide answers to the research questions that led this study. I will discuss the use of creative teaching to support teachers work and a better management of it. Furthermore, I will refer to creativity as a resource which needs a more in-depth implementation in disadvantaged realities.

In addition, I will consider which factors affect teachers' and students' expression of creativity. To do that, I will use a new model describing creativity in school science and its expression through creative teaching and teaching for creativity. These results were obtained through interpretative phenomenological analysis (IPA), a qualitative approach that was discussed in **Chapter 2** and **3**. In this research, the study of creativity and creative science teaching is settled in Scotland, where the state education system is guided by the Curriculum for Excellence (CfE), that is a curriculum with strong constructivist basis (Education Scotland, 2019b, 2022b). Hence, I wanted to explore to what extent CfE requirements are perceived suitable in terms of creative teaching and teaching freedom by secondary school science teachers.

5.2 Discussion of findings

The previous chapter was developed referring to the three research questions and presenting the findings extrapolated from the data. **Table 5.1** shows the data which generated the findings and the resulting main outcomes.

Table 5.1. Summary of the research outcomes from the findings and the data used

Research questions	Findings	Supporting data	Main outcomes
RQ 1. What do Scottish secondary school science teachers consider creativity to be in the context of teaching and learning science?	1. Teachers' view on creativity mostly agrees with the characteristics generally identify in literature.	Theoretical literature research, semi-structured interviews.	Main characteristics of creativity (novelty, originality, usefulness, meaningfulness) are recognised by teachers, but to different extent.
RQ 2. What are teacher perceptions of CfE's expectations around creativity across the curriculum, and how do these expectations relate to the daily classroom practices of science teachers?	2. The different curriculum stages support creativity discontinuously.	Theoretical literature research, semi-structured interviews	Majority of teachers have issues in considering CfE a constructivist flexible curriculum during the Senior phase, *i.e.* when preparing students to sit National assessments
RQ 3. What teaching approaches do science teachers report using to incorporate creativity into their lesson?	3. The routine practice of science teaching shows teachers striving to include creativity in their lessons.	Theoretical literature research, semi-structured interviews.	Novelty is recognised by teachers as common characteristic of a creative lesson. Different contribution to engagement are achievable through interdisciplinarity or referring to students' lived experience. The large number of topics included in CfE prevents teachers from deepening them in the classroom. The science assessments' structure is led by National assessment requirements.
	4. Teachers' plans for implementing creativity rely on curriculum knowledge, resources available, differentiated tests and building up relationships with pupils.	Theoretical literature research, semi-structured interviews.	Time lack's concern drives topics delivery in the classroom. Differentiated assessments in accordance with students' skills are preferred by teachers, though more difficult to evaluate and often possible only during the BGE phase. Building up relationship with students improves their engagement in the lesson.

5.3 Teachers hold a consistent view of creativity.

Some teachers still consider creativity connected to the art disciplines, or at least believe that students cannot relate it to science. Actually, this myth has historical roots and dates back to nineteenth century during the Romantic period, but its influence is still observable nowadays, whenever artists challenge themselves in expressing art creativity through science, or when scientific outcomes are expressed through art works. However, this myth tends to underestimate creativity in science with respect to the art one reducing the first to a mere exercise of logic and deduction while neglecting the creative process of reasoning. Even a festival such as 'Unboxed: Creativity in the UK' (UK Government, 2022), which took place on March 2022 until November of the same year and costed to the Government 120 million pounds, resulted to be mostly an artistic representation of science. In fact, this festival was meant to be a celebration of creativity across the country dedicated to Science, Technology, Engineering, Art and Mathematics (STEAM), and found its expression in ten projects such as the realisation of a statue representing the solar system, a field of dandelions shaped like lightening cubes, or the conversion of a decommissioned North Sea offshore platform into an art installation. This approach to creativity seems to acknowledge its presence in science only when it is represented through art. In general, believing in creativity myths can produce issues, and for example this specific myth can lead to limiting creativity education only to art classes. Actually this is a common point of view in fact, in a recent international study (Beghetto, 2010; Benedek et al., 2021), investigating the opinion on creativity myths of 1417 laypeople from Austria, Germany, Poland, Georgia, China and the USA, showed that one third of the interviewees still hold on to this preconceived idea.

Interestingly, most scholars dropped the distinction between art and science creativity preferring to look for its general characteristics.

The working definition of creativity used in this research (see **Section 2.3**) was developed assuming that it is a capability belonging to everybody which can be enhanced or impoverished, where its characteristics are novelty, originality, usefulness, and meaningfulness (see **sections 2.2** and **2.3**), and depends on education, personality, and social status (see **Table 2.1**). However, the analysis of the data gathered showed that the complete set of characteristics of creativity could be recognised only in one teacher's answer out of the twenty-one interviewed, whereas the answers of more than half of them could be related to novelty (fourteen teachers) and originality (thirteen teachers) (see **Tables 4.4** and **4.5**).

The sense of usefulness and meaningfulness were tracked through the data through an in-depth analysis of teachers' transcripts, but mainly referring to two questions reported in **Chapter 4** (see **Section 4.2.1.1, Table 4.6**). One of them was already included within the eleven questions of the semi-structured interview (*The CfE asks you clearly to enhance the creativity of your students. In which way do you meet this request?* – Question A), whereas the second (*Do you think that teaching in a creative way, enhance students' creative skills* – Question B) originated from a paper dated back to 2013 (Banks Gregerson et al.). In this paper, the authors argued that to develop a creative teaching, teachers should enhance their creativity, or should teach with the purpose of nourishing students' one by modifying the curriculum or building up creativity-oriented activities around it. The reason why the first question (Question A) did not result in a clear answer showing the importance teachers give to creativity in terms of usefulness and meaningfulness was due to its association with another one that diverted their attention (*Do you have sufficient freedom or support to do that?*). All the eleven teachers I asked if creative teaching enhances creative skills answered affirmatively to question B, similarly seven out of the ten remaining teachers recognised to boost students' creativity through their teaching (Question A). The combination of the answers to these two questions resulted in a much higher percentage of teachers giving value to their creative teaching in terms of usefulness and meaningfulness, in fact eighteen out of twenty-one recognised both the characteristics.

5.4 Curriculum for Excellence's discontinuous requirements during the BGE and Senior phase affect teachers' autonomy and their ability to foster creativity.

The curricular guidelines of CfE are considered by most of the teachers quite flexible. The underlying principles from pre-primary to primary and then to the end of the secondary school are the same and require teachers *'to help the children and young people gain the knowledge, skills and attributes needed for life in the 21st century, including skills for learning, life and work'* (Education Scotland, 2019d). In order to do that, it provides quite detailed instructions on the topics required to be delivered in each discipline and strongly suggest using different teaching techniques and assessments respecting students' learning pace and skills.

However, some discontinuities are observable in the transition from the BGE phase to the Senior one and the teachers who participated to this study confirmed these issues talking about performativity effect and alternative solutions they adopted to deliver a more effective teaching (see **Section 4.3.1.2**).

The constructivist roots of CfE supports a learning environment which focuses on, and develops, student' skills (see **Chapter 2**) however, achieving this is not an easy task for most of the teachers I interviewed, especially during the Senior phase, *i.e.* from the fourth to the sixth year, when students need to get ready to sit the National assessments. Twelve teachers out of the twenty-one interviewed reported that they experienced pressure due to CfE requirements, mainly connected to a perceived lack of time (see **Table 4.7**). In fact, despite the BGE phase should last until the third year of secondary school, it is a common practice to shorten it to the advantage of the Senior phase, in an effort to mitigate the pressure due to the lack of time (Ball, 2003, 2008). The shortage of time experienced by the teachers is just one of the factors that contribute to performativity effect which affects teachers pushing them to have an individualistic approach in their teaching, only looking for productivity and striving for excellence. Under the pressures of performativity, teachers are pushed to deliver assessment outcomes that are set externally, with the resultant increase in stress and anxiety, eventually followed by motivation loss (Boldyrev, 2016;

Spicer et al., 2016). In this sense, families, society, and sometimes departments do not help much to relieve pressure on the teachers, as they are focused on ensuring pupils a place in colleges or universities and this clearly contributes to the performativity effect too. In fact, the Scottish National assessments are 'gatekeeper' qualifications, which are a pre-requisite of entry to university in Scotland, which along with the high quality of education offered are among the few free further education institutes left, at least in the UK. In this respect, the pressure related to National assessments was identified by seventeen teachers and was mainly due to the quantity of contents required to get the pupils ready to sit the exams, hence to an overloaded curriculum. However, teachers also highlighted the presence of an unclear marking system, associated with questions meant to test knowledge rather than skills and written in a complicated language. The pressure, the stress, the frustration, and the anxiety experienced by the teachers in covering all the topics requested by CfE in preparation for National assessments limits or even precludes any cooperative work with colleagues. This is not avoidable if the time to deliver all the required topics of their subject is perceived not sufficient.

The *'performances'* of teachers and schools are then evaluated according to students' grades at the National assessments, their trend to continue their studies within further education systems and their capability of getting a job within a few years after the degree. These evaluations result in the publication of school rankings, which have the power to drive families to move to areas with high-rated schools and to take Government funds away from "less" deserving schools.

Hence, the effect of performativity, which most of the teachers interviewed for this study described with words, such as *pressure*, *lack of time*, and *frustration*, results in forcing the teachers to give up more creative teaching in favour of a more traditional one, mainly based on memorising and repeating concepts, theories, and formulas. The pressure experienced by the teachers has an indirect impact on students as well, as they are often forced to select the subjects they want to deepen and eventually prepare for the higher levels of the National assessments in the middle of the second year. This choice contributes to students' disaffection towards the disciplines they did not choose (see **Section 2.7.1**), which will be abandoned in the fourth year.

Furthermore, the lack of resources such as time, money, and space can exacerbate teachers' perception of performativity heavily affecting their work and consequently students' learning. In extreme cases, lack of resources might even lead to teachers' burnout and consequently impact their approach to creativity (Betoret, 2009). Indeed, time was the resource that most of the interviewees reported perceiving the lack. In fact, more than half of the teachers, twelve out of the twenty-one interviewed, perceived a constant lack of time in delivering the CfE contents, whereas only three highlighted the lack of money or space as the major limitation placed upon them (see **Table 4.7**).

5.4.1 Rising doubts on the impact of assessments training on creativity

Teachers tend to resort to flexibility in the assessing procedures mainly in the BGE phase (see **Section 5.5**), and in this respect the Scottish curriculum does not restrain these assessing methods exclusively to the BGE phase. However, teachers are aware that there is not much time left for different forms of assessment when the students are required to take the National ones. The Senior phase assessments usually include multiple-choice questions, fill-in exercises and eventually open-ended questions (SQA, 2022)to which students are given detailed instructions on how to answer. Teachers questioned about their preference in posing open-ended questions with respect to multiple-choice ones (*Do you prefer to pose your students open-ended problems or multiple-choice questions?*) recognised the importance of using both within the assessments. But when asked which one they consider contributing the most to creative teaching (*Which questions do you think are more useful with respect to the development of creative thinking?*), the large majority of them, eighteen out of twenty-one (see **Section 4.4.1.2**, **Table 4.10**), associated open-ended questions with creativity, and within those eighteen only two (Jamie and Timothy) argued that creative thinking can be triggered by multiple-choice questions too.

The perceived inevitability of training students to answer to open-ended questions is a clear consequence of the performativity pressure experienced by the teachers when dealing with National assessments. Obviously, giving students detailed instructions on how to answer to them provides the positive feedback of getting successful results to these exams. However, this approach to education might deprive students of developing their creative thinking and problem-solving skills. In fact, the association between creative thinking and problem-solving questions, which are open-ended by definition, is known and has been widely explored (Drake et al., 1984; Hong et al., 2009; Runco, 1994). In this respect, Marquardt argued that *'creativity requires asking questions for which an answer is not already known'* and this is due to the fact that *'innovation is rarely the product of pure inspiration, that "Eureka!" moment when some genius comes up with a wholly new idea'*. Instead, *'innovation happens when people see things differently. It starts with a questioning culture that helps people gain new perspective and see things differently. Innovation is generated by great questions in an environment that encourages questions'* (2014).
Interestingly, despite teachers acknowledging the relationship between creative thinking and open-ended questions, they did not recognise that training students to answer them set boundaries to creativity in fact, only eight of them recognised this issue. Moreover, preparing students for the National assessments, despite teachers' belief of limiting their creativity, becomes a matter of responsibility, as students' failure at the exams is perceived by teachers as their own failure. It is not improbable that it is the nature of teaching itself which causes these feelings in fact, teaching can be considered an *'emotional practise'* (Hargreaves, 1998), where teachers' emotional connections and commitments with students is the 'engine' guiding the way they teach and plan their lessons. The holistic involvement of teachers in their job might become the cause of an emotion of guilt, where the efforts made are not considered sufficient, which has been explored by several scholars (Farouk, 2012; Hargreaves & Tucker, 1991). Hargreaves *et al.* explored the feeling of guilt experienced by primary school teachers generated by a narrow and excessive commitment to care, insufficient connections between teachers and a *'growing time demand of accountability'* (1991, p. 503). These characteristics associated with a perfectionist personality might

lead to teachers' burn-out, that however, could be avoided by reducing constraints and demands on teachers and improving networking. This is also confirmed by a study held in England by Brackett *et al.* on emotion-regulation ability (ERA) in 143 secondary school teachers showed the importance of social support, especially referred to principal support, and job satisfaction deriving by positive affect while teaching in avoiding burn-out (2010).

5.5 Deploying engaging and interdisciplinary lesson can help teachers in developing a creative lesson.

Multiple studies highlighted the importance of developing a constructivist environment in the classroom to enhance a more efficient learning. The characteristics of the constructivist and the didactic ones were reported in **Chapter 2** (see **Section 2.5.2**), showing the differences between these two opposite environments (see **Table 2.2**), where the latter recalls more traditional teaching approaches (Beghetto & Kaufman, 2014; Davies et al., 2013). In school science teaching, the scientific method is still very much used and fit the requirements of a constructivist school environment, which is based on active learning. On the other hand, using a didactic approach or 'transmission teaching' as it was termed by Douglas Barnes (1976) that involved writing on the blackboard and urging students to copy from it is an outdated method which belongs to a traditional teaching approach that teachers following a more constructivist one tend to decline (Scerri, 2008). The lack in effectiveness of this traditional approach is reported in literature too. For example, a study dated back to 2012 showed that even pre-service teachers exposed to different teaching styles during their Bachelor of Education program found the *"chalk and talk"* traditional teaching less effective compared to more modern and engaging ones (Laronde & MacLeod). Here it is worthwhile noting that the paper's authors invite the reader to consider the fact that usually teachers will tend to reproduce the teaching style they learned during their teaching education program.

However, an approach to learning centred on respecting students' learning pace and skills, diversified learning, and hand-on activities is still far from being adopted when referring to school science. The reasons why teachers struggle in adopting this approach are many and span from the pressure connected to the National assessments to the perception of a lack of time and resources or more generally to the performativity effect (see **Section 2.7.1**). These issues, which will be explored more in detail further on in the chapter, are confirmed by the data collected in this study, highlighting the difficulties experienced by the teachers in pursuing a successful science learning free from any form of pressure on their teaching approach.

Science teaching and learning depend on teachers' teaching approaches, which are influenced by the number of topics to be delivered, by the chance of developing interdisciplinary curriculum and assessments, as well as by the knowledge of the class in terms of students' skills, interests, and background. In this sense, creativity can help in developing stimulating interdisciplinary curriculum as well as in projecting assessments meant to enhance this soft skill in students.

Deployment of more engaging and interdisciplinary creative lessons can correspond to a lightening of the curriculum overload experienced by teachers. However, delivering a creative lesson means respecting the characteristics of creativity itself in terms of novelty, originality, usefulness, and meaningfulness (see **Section 2.3**), which can be difficult when faced with a high number of curriculum's topics. Furthermore, the use of a variety of different assessment methods are often restricted to the first and second year of BGE, whereas in principle it should be extended at least until the third year. The choice to start the Senior phase a year earlier depends on the school's policy and the teachers' perception of time in covering all the benchmarks recommended by CfE (which contributes to performativity effect) pushes them to select and deliver just some of them.

In this respect, several scholars are studying the effects of an overloaded curriculum on teachers and students and it was observed that the difficulty in covering or deepening the various topics generally results in an increase of "shadow education" (*i.e.* private supplementary tutoring) with growing policy implications in Europe (Bray et al., 2021). Shadow tutoring is a very widespread phenomenon in Eastern Asia mainly for cultural reasons and is currently increasing in Europe. In his paper, Bray and colleagues argue that the spread of this phenomenon in Western Europe is due to the *'advent of marketization alongside government schooling'* (p. 441), with governments implicitly supporting it. An article dating back to 2013 reported that 40% of Italian secondary school students resorted to private tutoring (Campani). Similarly, in England and Wales according to a survey of 2381 students aged 11-16, 41% of London's pupils receive private or home tutoring, with this proportion being lower (27%) in the rest of the country as well (The Sutton Trust, 2018). This parallel form of education is understandably not accessible to all families and is contributing to increase the inequality gap between students with different backgrounds. For example, without going any further and referring to the data gathered for this study, the teacher who mentioned parents' resorting to private tutoring works in a very affluent school in Glasgow. Besides the same families who can buy additional tutoring can also pay for arts activities, such as music lessons, art classes, or dance classes.

However, shadow education is just a consequence of an overloaded curriculum. In fact, teachers perceive an overload in curriculum contents, due to the tendency to include new contents to it without removing any and not considering the amount of time required to develop them all (OECD iLibrary, 2020). The Organisation for Economic Cooperation and Development (OECD), which is a forum of 38 democracies cooperating to develop policy standards and promote sustainable economic growth, recognised some common strategies to lower curriculum overloading (OECD iLibrary, 2020). OECD suggests focussing on the essentials and *'on conceptual understanding or big ideas'* avoiding an excess of topics, developing a coherent learning process in accordance with grades and education levels, and adapting the size or format of curriculum documents considering the overload perception. Widening the number of curriculum topics is not mirrored by an increase of the school time, which can result in low teaching performance together with a worsened students' and teachers' well-being. In fact, the consequences of many benchmarks to be covered associated with the performativity effect perceived by teachers affect the self-confidence of students' who are surrounded by a competitive school environment (Federičová et al., 2018).

5.5.1 Teachers' perspective on creative lesson and issues related to its realization

Developing a creative engaging lesson, which provides an interdisciplinary learning, depends on several factors. Along with having a constructivist school environment, it is necessary to rely on a flexible curriculum, and have the chance of using different assessing methods.

To achieve an in-depth understanding of the data collected, it was necessary to write a working definition of a creative lesson, which considered all these factors. This definition was meant to understand teachers' idea of it, along with exploring their perspectives on students' engagement and interdisciplinary curriculum.

The reference definition of creative lesson described in **Section 2.7.2.1**, was the following:

A lesson is creative if the teacher is able to engage the students in developing their understanding of the subject under study in a novel way, commonly by exploiting interdisciplinary connections or using topics that are meaningful to students' lived experience.

This definition was intended to be a general one, applicable to all disciplines, although it was tested only with secondary school science teachers, and it is based on two key concepts, novelty and engagement. Novelty has been already analysed as a main characteristic of creativity (see **Section 2.3**), while engagement, when referred to school environment, is recognised to be the backbone of the constructivist approach (see **Section 2.5.2**). In this sense, the purpose of this definition was to present in one sentence the two key concepts of creative teaching, novelty, and engagement, and at the same time explaining how students' engagement should be achieved. In fact, a novel way of delivering a creative lesson can be achieved engaging students using topics that they can recognise as belonging to their everyday life or their interests. Additionally, a better development of transferable skills in students can be accomplished using an interdisciplinary approach, which is supported by a constructivist school environment.

The definition was presented to twenty teachers resulting in positive feedback from fifteen of them, whereas it was considered incomplete by two, and evaluated fairly positive by one interviewee and negatively by another (see **Table 4.8**). Among the teachers who commented positively on it, four of them recognised their teaching approach while delivering a lesson, while nine teachers focused on novelty and the remaining ones on the engagement techniques, but everybody gave an interpretation of the sentence proposed attending IPA expectations (Smith, 2004; Smith et al., 1999; Smith & Osborn, 2008a).

Several studies (Bolarín Martínez et al., 2013; Lansiquot, 2016; Moss et al., 2008; Snepvangers et al., 2018) argue that in order to learn effectively using a competence-based approach is necessary to develop an interdisciplinary curriculum, which is supported also by the constructivist education theory. Furthermore, an interdisciplinary curriculum would support the rise of networks of teachers resulting in stimulating activities and projects that would contribute to the fulfilment of teachers themselves as persons (Main, 2010; Park et al., 2005). However, expanding the science curriculum outside the *'boundaries'* of science disciplines is not trivial (O'Donnell, 2015; Thorburn, 2017), at least referring to the Scottish education system which does not include recurrent (or even annual) interdisciplinary curriculum meetings between different disciplines teachers within the schools' agenda. Moreover, the use of interdisciplinary connections within a lesson implies a series of requirements strongly dependents on school and curriculum management. Creative teaching should be developed by using an interdisciplinary overview of the curriculum, obtained through communication with colleagues of different subjects.

This may lead to developing a curriculum where subjects partially overlap thus creating a continuum in students' learning.

However, developing interdisciplinary contents and assessments accordingly is anything but easy as confirmed by the teachers who participated to this study. In fact, in general, as argued by some scholars (Moss et al., 2008), interdisciplinary assessments can be developed only if teachers have the possibility of delivering 'interdisciplinary' and 'transdisciplinary' curriculum. Rewriting all disciplines' curriculum would give students a comprehensive vision of the contents, showing them countless connections, and helping them to build many more. Nonetheless, this transformation process is going to be much more difficult if we do not consider the assessments as a part of it, and not just the end, in other words, they need to be shaped with the purpose of promoting the individual learning process. However, this is anything but simple in an education system as the Scottish one, where even the architecture of the Scottish school buildings did not offer a chance of interaction between teachers of different departments. In fact, the school buildings have all the same architecture: the school offices near to the entrance, a big hall on the ground floor, and then the different departments separated one from the other and located in different parts of the building. The bigger is the building the further the departments are from each other. This arrangement prevents interactions between teachers of different disciplines limits an eventual decision of developing an interdisciplinary content to disciplines of the same department.

So far researchers have studied interdisciplinarity in terms of teachers delivering interdisciplinary lesson or students' interdisciplinary learning (Bolarín Martínez et al., 2013; Moss et al., 2008). In the definition of creative lesson, there is a clear distinction between engaging students with an interdisciplinary approach or relying on topics meaningful to students' lived experience, because the conditions required to apply them are different. In fact, it is easier for teachers referring to topics that are meaningful to students' lived experience while delivering a lesson, as they can refer to everyday life or relate to them knowing their interests. However, knowing students' interest or building a relationship with them is not easy, in fact some teachers highlighted that working in small school might make a difference in this sense. This can be better understood considering that during a normal school day, students attend fifty minutes lesson' periods, and they are supposed to move from one classroom to another when the bell rings. Each department has its own classrooms, therefore the students are required to move within the department, if the following lesson is in the same department or move between departments, if for example they have to attend an English lesson after a Chemistry one. In this sense, the daily school life is very busy with not much time left for students to pause for a moment and speak with their teachers about themselves or for teachers to ask them something to knowing them better. In addition, the students usually change all their teachers each year, except for the Pastoral Care one, who will accompany them throughout all the six years.

Presenting to the teachers a working definition of creative lesson combined with their idea of creativity helped to create an understanding of to what extent they recognise and eventually deliver a creative lesson, and despite it received mostly positive feedback, it was evaluated incomplete by two teachers and negatively by another one.

In one case, the definition was considered a partial representation of what a creative lesson might look like, as it did not consider the contribution made by the participation of the students to the lesson (see **Table 4.8**, Rachel). This point of view opened up to few interesting reflections as it expressed the foundation of divergent thinking which is considered by scholars a fundamental characteristic of a creative lesson when associated with intrinsic motivation and creative problem solving (Baer & Kaufman, 2012; Runco, 2003; Silvia et al., 2008). However, the lack of students' contribution to the lesson levelled by the teacher was already included in the concept of engagement used in the definition, as students' engagement requires their holistic participation to the lesson. Whereas, the other evaluation of incompleteness does not appear to have solid bases, as the teacher justifies it with the impossibility of defining and measuring creativity, due its *'intangible'* nature (see **Table 4.8**, Mark). Indeed, defining creativity as *'intangible'* and possibly not measurable is another myth on creativity (Benedek et al., 2021) as there are several models describing it as well as tests to measure and evaluate it based on personality, flexibility, openness, or even IQ (Kaufman, 2014; Sternberg, 1985; Vartanian et al., 2018).

Finally, the definition of a creative lesson used in this study was evaluated negatively by one teacher, who recognised insufficient defining a creative lesson novel, if the topic that the teachers is delivering does not touch all the aspects of the curriculum (see **Table 4.8**, Simone). She used the expressions '*knowledge of the curriculum*', *'rights respecting curriculum'*, *'inclusive curriculum'*, and *'anti-racist education curriculum'*, which other science teachers might think out of place, because they believe science to be culturally neutral. The teacher's consideration of these wider themes and foci shows that they are thinking in an interdisciplinary way. The teachers responding to the requirements of the Scottish education system as reported by CfE have the responsibility of helping students to become *'successful learners, confident individuals, responsible citizens, and effective contributors'* (2019d). Behind the '*knowledge of the curriculum*', there are *successful learners*', '*confident individuals*', and probably '*effective contributors'* to the wellness of the society in the future. Hidden in the expressions *'rights respecting curriculum'*, *'inclusive curriculum'*, and *'anti-racist education curriculum'*, there are *'responsible citizens',* inclusive respectful individuals, who will be happy to live in a society open to all differences. Indeed, all the contributions to the lesson she identified are extremely robust especially if associated with the *'knowledge of young people'*, as they allow to build a personal relationship with the students increasing the chance of engaging them in the lesson. However, even recognising the importance of all the aspects covered in her answer, the relationship between the characteristics of the curriculum she wants to introduce in the lesson and creativity are a bit stretched.

5.6 Teachers routinely practice creativity in their science teaching and foster creative learning, depending on their socio-economic school context.

Creativity is considered a valuable skill in our society, and it is highly in demand in jobs spanning different fields such as art, business, and science (Easton & Djumalieva, 2018; NACCCE, 1999; Scott, 1995). Therefore, an educational approach oriented to the development of creative skills is going to offer students not only a personal fulfilment, but also the chance of a successful access to the job market.

In this respect, the study developed in this thesis which deals with the role of creativity in school carries even more weight due to the particular emphasis on how science teachers deliver a creative lesson and enhance the creativity of their students. The analysis of the semi-structured interviews of twenty-one science schoolteachers revealed that several factors are associated with creativity in school. Among these, the transition from a more conventional chalk-and-talk lesson to a teaching approach based on hands-on experiments certainly plays a primary role. This is even more true in the case of science learning that greatly benefits from any kind of laboratory work (Hofstein & Lunetta, 1982). Not only are laboratory activities known to facilitate students understanding of science, but also enhance their engagement and motivation in learning science as well as their scientific attitude.

Actually, hands-on activities do not always need expensive resources, which is positive because it makes experimental learning universally available. For example, Rachel, one of the teachers who took part to this study, achieved a similar result by asking her students to filter orange juice with and without bits on cheap filter paper. Similarly, Joan challenged her students to demonstrate the phenomenon of the static electricity at home with some simple experiments that were included in her lesson plan (**Appendix L**).

Analogous examples are also reported in literature. In a study published in 2016 (Susantini et al.), the authors asked 47 students to utilize available household materials to replace the glassware and equipment used in a standard DNA extraction protocol. This low-cost practical experience had the additional advantage of triggering the students to think creatively to alternative ways to plan and perform the DNA extraction. While the examples provided by Rachel and Joan seem to indicate that enhancing the student creativity might not necessarily rely on the availability of expensive equipment, they are probably more likely to represent a successful (and laudable) attempt to achieve a good result with the few available resources, a scenario that is very common in more deprived areas. In fact, some activities, such as the laboratory ones still do require expensive equipment, and not all schools have access to enough funding to promote hands-on experiences, as highlighted by three teachers who participated to this study (Darren, Jamie, and Karol). Engaging students in a theoretical lesson on radioactivity or having the chance of showing pupils α-, β-, and γ-radioactive sources and how a Geiger reader responds to them in presence of different screens is clearly going to have a different impact on students. Giving students the possibility of a hand-on experience, such as dissect an organ, instead of attending a demo performed by the teacher may enhance their curiosity toward the functioning of the body as a whole. Delivering a lesson on the concept of pH by performing an acid-base neutralization experiment or challenging them in using a flame assay to test the frequency of the light emitted by the electron transitions of different elements implies the availability of a chemistry lab, PPE[1], reagents, instruments, and glassware. Schools located in more deprived catchment areas have limited funding which are calculated on the basis of performance parameters such as the percentage of students achieving a good Higher or Advanced Higher evaluation at the end of their school path. Moreover, students living in more affluent areas are more likely to have either highly educated parents that can support them or pay for private tuition to obtain such a support, which are contributing factors to achieve better grades.

Therefore, providing additional funding to schools in deprived areas, regardless of their students' performance at the National assessments certainly seems a desirable

[1] Personal protective equipment such as lab coats, safety glasses, etc.

action if we want to enhance students' creativity by increasing their chances to perform hands-on experience.

Besides, exam boards often focus on formal laboratory activities, not everyday experiments hence, not doing standard experiments may disadvantage the students during the formal assessments. More generally, the availability of fully equipped labs, reagents and PPE offers the chance of boosting the number and types of hands-on experiences the students can have access to.

Limited access to labs and equipment is only one of the reasons for which deprived areas are less likely to contribute to the enhancement of creativity in school. Material and financial deprivation can influence creativity leading to the absence of enrichment, as it denies access to experiences, events or activities that would nourish the individual creative development. Three teachers who participate to this study highlighted how deprivation might be an obstacle to students' creativity due to lack of input from their families, access to courses, or lack of activities outside the school. In this regard, for example, living in a rural area means not having access to cultural events, or museum exhibitions (Betlej, 2021; Gong et al., 2020; Patel et al., 2015), or simply to after-school courses, just because it would be difficult to go back home as the last bus available is generally right after the final period bell. In contrast, teaching in a rural area may as well have a positive effect on at least some factors contributing to deliver a creative lesson. Nineteen teachers out of twenty-one agreed that a creative lesson should be linked to students' lived experiences (see **Table 4.9**), hence knowing their students better can help them in achieving this task. However, some of the interviewed teachers highlighted how getting to know their students is much easier in smaller schools where the lower number of pupils results in higher chances of interactions.

While rural areas are often classified as deprived due to their limited access to resources and activities, deprivation is more frequently linked to the family background and the social context of the students. These factors play a primary role in creating the right environment to enhance student creativity. For example, the outcome of those homework activities that are projected to increase the pupil creativity (e.g., Joan's request to realize and experiment at home to calculate the heat loss of a house) may be very different when comparing deprived and affluent areas. Students with highly educated parents are more likely to succeed in this kind of tasks as they can receive more support at home, even through private lessons as mentioned in **Section 5.5**. Moreover, given that homework may rely, at least partially, on families, the education level of the students' parents can make a big difference on their attainment (Archer et al., 2012) and inevitably contribute to increase the gap between deprived and not deprived areas.

This gap is confirmed by several studies dealing with the student performance during the lockdown following the COVID-19 pandemic, where the entire school system started to rely more on families than teachers, a phenomenon that exacerbates social class academic disparities (Goudeau et al., 2021). According to a recent publication (Tong et al., 2021) that analysed data originating from 5 different studies including a survey of 1.6 million people across 162 countries, high income has a positive impact on emotions such as self-confidence that is in turn associated with creativity (e.g. self-confident students are more likely to suggest unconventional solutions to problems as well as self-confident teachers are more likely to deliver a lesson using a novel approach, see **Section 5.7**).

Since enhancing creativity in school is highly desirable, identifying the most deprived areas will be paramount to understand where to act primarily. The Scottish governments published the first version of the Scottish Index of Multiple Deprivation (SIMD) in 2004 and subsequently revised it in 2004, 2006, 2009, 2012, 2016 and most recently in 2020. However, such index is far from perfect. In rural regions, the SIMD areas are so large that they do not include homogenous social contexts. In fact, it is believed that only half of the low-income families live in the postcodes classified as most deprived. Since it represents an area-based measure, the SIMD is likely to fail to capture individual circumstances. This limitation emerged in this study when the SIMD indices of the school catchment areas were compared to the perception of the interviewed teachers. In fact, no significant correlation was found between these two parameters and for the same SIMD index different teachers reported sometimes very different perceptions (see **Section 4.1.2** and **Appendix H**). This seems to indicate that using the SIMD to identify the areas more in need of intervention is at least problematic. This index could be associated with other parameters that are able to further capture individual situations such as the access to the free school meals, just to give an example. Deprivation is a social and political problem but working on improving social and economic deprivation may result in empowering creativity in people. Promoting tailored cultural events and activities in deprived areas, inside and outside schools, for example, would foster curiosity and may stimulate people willing to discover something more. Several scholars studied how nurturing creativity passes through a proper (constructivist) school environment (Baer, 2016; Baer & Kaufman, 2012; Beghetto & Kaufman, 2014; Davies et al., 2013). Even though this study aimed to investigate creativity in science teaching, it is important to remember that its flourishing is not only relevant or of importance to education but needs to be supported by families, society and the cultural environment (Campos Cancino & Moreno Mínguez, 2020; Liang et al., 2022; Sen & Sharma, 2013; Wolska-Długosz, 2015).

5.7 Implementing creativity requires an education process which involves both students' and teachers' development of their creative skills and self-confidence.

5.7.1 Enhancing teachers' creativity is the outcome of an education process addressed to them

In 2014, Beghetto argued that teaching for creativity is the result of a gifted education (Beghetto, 2014). In Scotland, people are required to attend specific post-university courses, such as the PGDE ones, or undergraduate paths (*i.e.* Chemistry with Teaching, Physics with Teaching, etc.) in order to become teachers. The PGDE courses have the important merit of giving students the chance of practicing their teaching skills during two placements periods in two different schools. These placements last several weeks, during which the students are supported and mentored by the schoolteachers. Moreover, these courses provide students with a knowledge of the school policy, but also their rights and duties. However, none of these experiences is aimed to educate the future teachers in developing a creative approach to teaching. In fact, the enhancement of teachers' creativity is the outcome of an education path which should be offered to them possibly during the PGDE courses. As a matter of fact, supporting teachers in their education to creativity means giving them the tools to stimulate and enhance creativity in their students.

In fact, CFE's requirement to help students enhancing their creative skills would imply teachers' knowledge of creativity not in an abstract form, but eventually through a proper professional development which could provide them the tools to imagine and plan a creative lesson. Creative teaching is left to teachers' personal initiative and will and yet, there are examples of support for creative teaching. For example, the one developed through activities such as thought logs, Meditation Day field trips and personal creativity projects by Piirto in Ashland University, Ohio, for over twenty years. Piirto's model was based on the assumption that to support students' creativity (specifically K-12 students) teachers should have experienced personally the creative process (1998, 2008). In a recent paper, Groman (2022) analysed the impact of Piirto's long-term programme and the idea of creativity of teachers who attended her course back in 2017-18 or even dating further back to 1990, noticing that they have a stronger belief in their own creativity and a more developed sensibility in perceiving their students creativity. In 1991, de Alencar wrote about teachers' misconceptions on creativity which led them to believe that only a limited number of students could be creative. However, his study showed that a creativity training encouraged teachers' confidence in their own creativity and *'increased awareness of their own creative abilities and of the ways to use these abilities in their work'* (de Alencar, 1991, p. 225). Creativity training focussing on problem solving and idea generation seem, and more in general on the enhancement of divergent thinking seem to be particularly effective in nurturing this soft skill (Rose & Lin, 1984; Scott et al., 2004).

Therefore, creativity should be considered a skill that can be enhanced in students, but it requires first to be a part of teachers' education, otherwise its misconceptions might affect their teaching approach as well as their evaluation of students. However, this assumption implies that teachers should have a clear idea of creativity and its characteristics as this knowledge would allow them to be creative in their teaching approach.

5.7.2 Teachers adopt different approaches in implementing creativity.

Teachers struggling with overloaded curriculum and willing to deliver engaging creative lessons rely on their knowledge of the curriculum, the available school resources, the use of differentiated assessments, and the knowledge of their pupils through building up relationship with them.

An extensive knowledge of the curriculum may result in delivering a creative lesson for example, due to teachers' increased expertise in the time management of the lesson period, whereas less experienced ones with a superficial knowledge of it generally tend to focus on delivering content rather than developing skills or attitudes. This approach can result in a poorly efficient management of the time to dedicate to each topic and to the selection of the subtopic to deepen.

Indeed, the CfE topics of each discipline tend constantly to pile up and in fact, this research repeatedly highlighted teachers' perception of time lack in exploring creatively a topic when analysing the performativity effect (see **Section 2.7.1**), and in various sections of the summary of data (**Chapter 4**, **Sections 4.3**, **4.4.1**, and **4.4.2**). The will of delivering a topic in a creative way is up to the teachers, but it is obvious that having more time might help. An in-depth knowledge of the curriculum might eventually help teachers in delivering their lessons efficiently in terms of time management. This may also result in using modern teaching tools such as for example hyperlinks-embedded teaching material, G Suite for Education®, or Screencast-O-Matic®, amongst other, that can help to project and deliver a creative lesson, and in this sense, the teachers I interviewed described several techniques they adopted to engage students during their lessons.

Before discussing resources teachers rely on, it is important to point out once again one of the premises of this study, which it is not meant to differentiate between long-term teachers and early career ones, at least not in terms of their ideas on creativity or creative lesson. In this regard, this choice of not differentiating between teachers' experience is led and supported by the IPA approach adopted for the data gathering and analysis, which is meant to give value to each single opinion and in this specific case to each single teaching experience.

School resources make a difference in the possibilities of developing a more creative curriculum and the implications of their lack can be reflected on the delivery of a lesson. However, the interviewed teachers, despite struggling with lack of resources, mentioned some examples of creative lessons such as the one already mentioned reported by Rachel, and her approach to filtration and dilution using orange juice with and without bits in her class. This is a clear example of delivering a creative lesson while referring to everyday lived experiences. Notably, the lack of resources such as space and money results in a vicious circle which can impact the teaching delivery for a long time. In fact, schools settled in the most deprived areas quite often rank at the bottom of the school ranking table as measured by the Scottish Government (Scottish Government, 2020, 2022; SQA, 2020a, 2020b), which implies more difficult access to funds that could improve for example laboratory or class supplies, common spaces, or a better-stocked library.

Relying on differentiated lessons and assessments to engage students in the class activity and evaluate them with respect to their skills and strengths is an option chosen by several teachers, a choice that is supported and promoted by CfE. In fact, these teaching approaches and evaluation techniques offer to the teachers the possibility of enhancing students' engagement in the lesson and boost their confidence through their positive results. Indeed, the discussion over differentiated teaching, learning and related assessments is very lively between scholars. Mills (2014) strongly believes that learners should be evaluated through differentiated assessments, taking into account their different learning profiles, interests and readiness levels. In fact, he resists the common notion that all students should undertake the same task, as *'having different tasks for different students will not challenge all students intellectually'* (Mills et al., 2014, p. 335), and claims that differentiation and high-quality assessments practice can co-exist (McTighe & Brown, 2005; Moon, 2005; Tomlinson, 2005). In this regard, Moon (2005) considers three key concepts characterizing differentiated learning, which should be active, imply high expectation with appropriate scaffolding and occur in a social context. The social context claimed by the author is the classroom itself, where the assessment should offer opportunities for individual and collaborative work, which anyway are the characteristics of learning, to make sense of the assessment's instructions. In conclusion, teachers have the chance to *'eliminate barriers to demonstrating achievement'* (Tomlinson, 2005, p. 265) planning differentiated assessments with the main and only aim of respecting the same learning objectives and assessing criteria, while being meaningful and intellectually demanding.

Finally, nurturing interpersonal relationships gives access to that information that allows teachers to plan lessons that can relate better to students' life experiences, engaging them more effectively, and eventually providing teachers with the possibility of delivering a creative lesson. However, building up these relationships might be difficult as teachers change every year to get students used to different teaching styles. Furthermore, this educational approach might be more problematic in big schools, where, as mentioned, the pastoral care teacher is the only one they will not change along the degree programme. The teachers' efforts to develop a trustworthy relationship with students is essential as it opens to their engagement in the lesson as confirmed in a systematic review that included forty-six papers reported in a review dated back to 2017 (Quin, 2017). This systematic review shows that there is a strong relationship between students and teachers is *'associated with higher levels of psychological engagement, academic achievement, and school attendance and reduced levels of disruptive behaviours, suspension, and dropout'* (p. 373).

Students' engagement is an essential feature of a creative lesson of the working definition of creative lesson adopted in this study and implies a link between the possibility of delivering creatively a topic and the relationship between teachers and students. The efforts in building a good relationship with students is evident in the words of the teachers who participated to this study whether they recognise it necessary to support them, engage them more in the lesson, or offer the chance to develop an effective lesson.

5.7.3 The expression of creativity can be supported by enhancing teachers' and students' self-confidence.

Building a relationship with students means being able to recognise their skills, hence a soft skill such as creativity, which made worthy exploring teachers' opinion on the characteristics of creative students. This study offered the chance to notice teachers' efforts to build up relationships with students, the commitment to support their self-confidence and, consequently, to nurture their creativity.

5.7.3.1 Teachers' point of view on the characteristics of creative students

The characteristics of creative students acknowledged by the interviewees are disconnected from their idea of creativity and creative lesson, where it is possible to recognise some common features, such as novelty and originality for example. In fact, the transcripts' analysis confirmed teachers looking at students' self-confidence, skills management, diversified interests, or less often personality when attempting to recognise their creative skills. Teachers were asked which personal trait they associated with the students who they recognised creative (*What personal trait do you associate with the students you teach who are creative?*) and suggested a couple of characteristics they might have observed in their teaching experience (*Describe the profile of a typical creative student, e. g. extroverted, highly organised, self-assured*). The suggested examples were meant to be an ice breaker for our conversation and proved to be essential as some teacher found the question hard to answer and remained silent. In fact, this reaction is not unusual and for this reason the IPA practise suggests avoiding direct questions in semi-structured interview, as they might result in an interviewee' silence (Adams, 2015; Longhurst, 2009; Schmidt, 2004). Indeed, in IPA theory the writing of the questions is just one step of a long process, that is the development of the semi-structured interview itself. In fact, the researchers, who are key figures of IPA studies, must take care of the interviews' setting, the interviewees' comfort, and being an empathetic and prejudice free point of reference. Hence, the questions must be as open as possible to allow the participants to describe their experience with their own words.

The role of personality in creativity has been studied from different points of view, and in this sense, there are several studies in literature reporting it (Feist et al., 2017a, 2017b). For example, the Five Factor (or Big-Five) model links creativity to personality factors such as openness, extraversion, neuroticism, agreeableness, and conscientiousness (Feist, 1998; Hornberg & Reiter-Palmon, 2017). Notably, the proposed idea of personality-driven creativity is strongly in contrast with a large amount of data collected in this study. In fact, most teachers I interviewed stated to exclude the dependence of creativity on personality, whereas in some cases acknowledged the dependence on self-confidence, which is not a personality feature, but depends on environmental factors such as family, society and education. In fact, within the teachers interviewed only three considered creative students extroverted at least to some extent, whereas most of the teachers did not recognise any connection between personality and creativity. Instead, they highlighted the importance of being able to *'organise information'* and understand *'how one set of information or one idea connect to the other'* (Carter). A couple of teachers mentioned the sometimes-overused expression which define creative people as the ones who *'think outside of the box'*, who would look at an output and then produce something completely different. The idea of *'thinking outside of the box'* associated with creativity is not new in literature (Corazza, 2014; Glăveanu & Clapp, 2018), where the nature of the box walls are identified with rules, laws, theories commonly accepted by the society. In scholars' theories, we are supposed to overcome them to be free of generate new thoughts. Outside of the box it is possible to use old concepts and blend them to obtain new ones as in the conceptual blending theory (Koestler, 1969; Turner & Fauconnier, 1999), or to look at problems from different perspectives achieving new solutions through divergent thinking (Guilford, 1967; Kaufman & Sternberg, 2010b). These outcomes recall those reported in a recent cross-cultural study (Karwowski et al., 2020) that explored teachers' view of creative students. In this paper, the researchers collected the survey of nine hundred and twenty-two primary and secondary teachers from Australia (300), Italy (243), Poland (272) and the UK (107), identifying ten creativity characteristics observed by the teachers in their students. Within these characteristics, the teachers I interviewed recognised curiosity, imagination, the capability of *'seeing relationships between ideas'* (p. 9) and *'combining knowledge from different domains'* (p. 9) which resulted to be the most common descriptors for creative students in the paper. Previously, I analysed the expression *'thinking outside of the box'* in terms of divergent thinking and conceptual blending theory, and I think that this wording hides the capabilities of *'seeking new solutions'* (p. 9), *'coming up with many solutions to a single process'* (p. 9), and *'noticing many aspects of a single* *problem'* (p. 9) mentioned in the paper. The three last characteristics of creative students mentioned by Karwowski et al. were *'having many ideas on their own'* (p. 9), *'having the ability to think independently'* (p. 9), and *'having initiative'* (p. 9) which I did not find in the words of the teachers I interviewed.

Teachers' ideas of students' creativity features were quite heterogeneous, but some overlap sometimes emerged. In fact, some of the recognised features falling under the spectrum of self-confidence. All teachers recognised the importance of nourishing students' self-confidence to support them during their growth, although only eleven teachers identify it as a main feature of creative students, as showed in **Table 4.12** and **4.13**.

Teachers recognising self-confidence as the common characteristic of creative students, agreed on the fact that creative students, regardless of their personality, will *'be brave'*, *'take risks'*, *'ask questions'*, or *'defend their own opinions'*, quoting few expressions used by them (Craft, 2004; Cropley et al., 2019; Daud et al., 2012; Feist et al., 2017b; Karwowski et al., 2020; Soh, 2017).

If creativity is not innate in an individual and can be strengthened or weakened by many factors, so is self-confidence. For example, an over-protective or aggressive parent, a deprived background, a possessive partner, or a strict teacher will all contribute to lowering a person's self-confidence. The teachers I interviewed are fully aware of their role in helping students to develop their self-confidence, and believe that creating a connection with them based on the knowledge of their background and preferences (*i.e.* outside of school's hobbies, and activities) are effective tools to help them enhancing this capability. Enhancing students' self-confidence is going to improve their wellbeing with possible positive impact on the their willing of knowledge and consequently improving school outcomes (MacLellan, 2014), but its development might have also a deeper effect on their growth.

Indeed, some teachers confused being shy, quiet or introvert with a lack of confidence and being extrovert with being highly confident, which is not uncommon. At least one third of people in common society is introvert, which is a characteristic preventing school and University students to actively participate to lessons, ask questions, and be enthusiastic performers (Cain, 2012). Nowadays, forms of expression such as active listening, taking good notes, or silent thinking are underrated and this is indeed a form of performativity, related to what Prof Macfarlane in an article for the Times Higher Education Supplement calls *'Western assumptions about the dialogic nature of knowledge construction'* (2014, p. 45). He argues that the successful export of the Western model of higher education in the Asiatic countries, enforced the stereotype of Western students being *'confident talkaholic'*, emphasising this performativity effect. There are courses and activities organised in schools and universities to convert people in *'pretend extrovert'* (Cain, 2012), although, as expressed by Carter, shy students do not have a problem with being confident in their ideas, but in the way they may be required to delivering them.

To the best of my knowledge the contribution of self-confidence to creativity has not been explored yet. This result is even more interesting if we consider that all the teachers who recognise this relationship work in mixed or deprived areas, except one (Darren) who works in an affluent one but has an extensive experience in working within more deprived realities.

5.8 Creativity in school science: a new model.

The working definition of a creative lesson reported in this research focuses on the teacher's deployment of creativity. In fact, a creative lesson involves the teacher's ability to design and implement innovative teaching strategies. This aligns with key themes of the study, such as the necessity for teachers to adapt their approaches to curriculum constraints and student needs (see **Section 4.4.1** and **5.5.1**). Teachers willing to deliver a creative lesson will incorporate novelty and engagement, creating lessons that differ from traditional models while adhering to educational standards. However, a creative lesson has the dual function of helping students understand the topic under study and fostering their creative skills, encouraging divergent thinking, problem-solving, and interdisciplinary connections.

As mentioned in **Chapter 2**, the Scottish education system requires teachers to enhance students' creative skills (see **Section 2.7**) allowing them to *'develop and demonstrate their creativity'* through active learning (Scottish Government, 2004). However, CfE does not give any instruction to teachers about the actions they are expected to put in place to perform this task, showing either a lack of interest toward their teaching approach or eventually the intention to leave a certain degree of freedom to the teachers to express their original approaches. Basically, CfE only considers the final product of teachers' work, *i.e.* students' creativity, which is the intended outcome of teaching for creativity. However, creativity in school education and more in particular in school science, which is the main focus of this study, is the result of a combination of creative teaching and teaching for creativity.

Creative teaching is the result of a novel and engaging approach to teaching. Novelty is commonly acknowledged by literature to be a characteristic of creativity and referring to the data of this study, fourteen teachers out of twenty-one recognised it as such (see **Table 4.5**), and actually all the teachers confirmed its role in a creative lesson (see **Table 4.9**). Whereas, referring to the definition of creative lesson used, the meaning of engagement is related to a holistic participation of the students to the lesson (see **Section 2.7.2.1**). According to that definition, students' engagement can be obtained using interdisciplinary connections or *'topics that are meaningful to students' lived experience'*. In fact, nineteen teachers out of twenty-one confirmed the importance of using topics meaningful to students to project a creative lesson, whereas twelve of them recognised the use of interdisciplinary connections. However, novelty and engagement are generally achievable when teachers are allowed to work on a flexible curriculum, and despite CfE being considered as such, they perceive this flexibility only during the BGE phase (see sections **5.4** and **5.5**). Once teachers and students face the Senior phase, their efforts are all addressed to deliver and stock all the knowledge necessary to students to sit the National assessments, eventually leaving creativity behind. Novelty and engagement depend on the resources available and the consequences of their lack have been explored in this chapter, where the association between the lack of time and the choice of delivering a creative lesson has been discussed (see **Table 4.12**). Active learning is a foundation of the constructivist approach (see **Section 2.5**) and allows teachers to engage students in the lesson proposing topics in a novel way. Besides, active learning associated with the suitable resources gives access to several practical activities. Finally, the knowledge of students' skills, interest, and background can open up to novelty and engagement in the lesson, suggesting teachers' novel approach to the delivering of a topic (see **Section 5.7.2**).

Hence, the concept of a creative lesson has two dimensions which involve the teacher's role and the student's which are captured in my proposed model of creativity in school science (**Figure 5.1**). This model wants to highlight that creative teaching (teacher-driven) and teaching for creativity (student-centred) are interdependent. The teacher facilitates an environment where students' creativity can flourish by employing creative methods themselves.

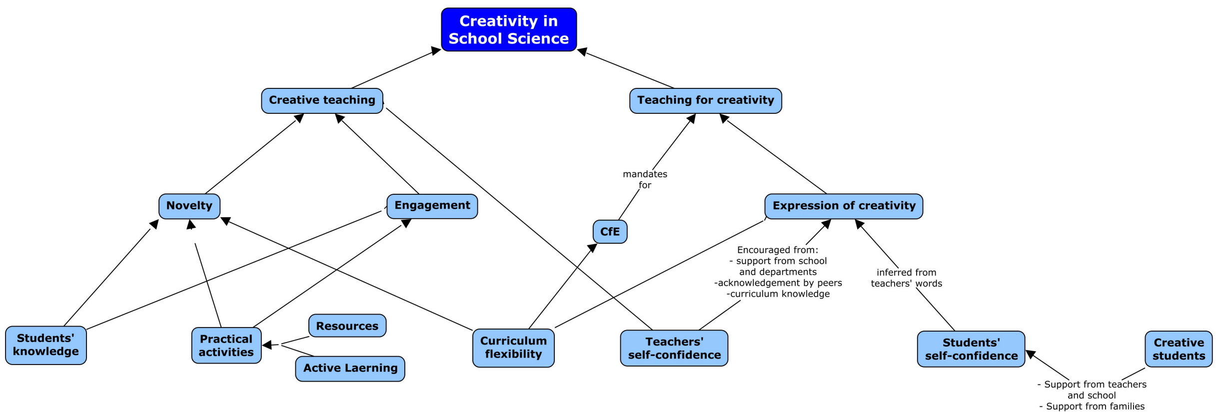

Figure 5.1. A new model of creativity in school science

The data analysis of this study supported by literature (Banks Gregerson et al., 2013; Dehaan, 2009; Tran et al., 2017) demonstrated teachers' belief that students' creativity can be augmented through teaching and that teaching for creativity is achievable through creative teaching (see **Table 4.6)**, these results were inferred from the analysis of teachers' answers to the aforementioned questions A ('*The CfE asks you clearly to enhance the creativity of your students. In which way do you meet this request? Do you have sufficient freedom or support to do that?*') and B ('*Do you think that teaching in a creative way, enhance students' creative skills?*'). Furthermore, there is a connection between teaching for creativity and both teachers' and students' self-confidence. When teachers and students are supported in their self-confidence, they feel free to express their creativity and the expression of creativity is strictly dependent from teachers' access to a flexible curriculum, and by a strong knowledge of it. This requirement is even more important if we consider that CfE mandates for teaching for creativity. Teachers' self-confidence in delivering a creative lesson is influenced by the support they receive by their colleagues, department, and school in acknowledging their novel teaching approaches. Indeed, a creative product must be acknowledged by others in order to be considered as such. As a consequence, the enhancement of teachers' self-confidence would be a stimulus to approach teaching in a creative way.

Finally, the existence of a connection between students' self-confidence and creativity can be inferred from the words of the interviewed teachers. Scholars as well as the constructivist theory in general, strongly support the requirement for teachers to promote self-confidence in their students (MacLellan, 2014; Sheldrake, 2016; Swan, 2012) and all the interviewees agreed with this idea. Clearly, boosting self-confidence should not be considered only a teachers' responsibility as other factors such as family and society also play primary roles. However, surprisingly, when questioned about the characteristics of creative students, all the teachers working in a mixed or a deprived area identified as creative the most confident students. In their opinion, creative students are *'brave'*, *'take risks'* and are not afraid of their peer's judgement. Within the teachers working in more affluent areas, only Darren thinks that self-confidence is a characteristic of creative students, though his opinion originated from his previous experience in more deprived schools. Creative students are confident in expressing their creativity, and their expression of creativity is the only observable parameter that can be evaluated. However, a one-to-one correlation between creative students and self-confidence cannot be observed, meaning that creative students are self-confident, but not all self-confident students are creative.

This model can provide school professionals with a comprehensive scheme of those factors that can contribute to teaching with and for creativity and can be used to identify actions and plans aimed to fulfil the CfE requirements of promoting and supporting students' creativity.

5.9 Conclusions

The discussion of the collected data developed in this chapter was led by the research questions and the five findings summarised in **Table 5.1**, whereas the literature in support justified the statements which titled the various sections. The enhancement of creative skills is recognised to be fundamental in the achievement of a personal and professional fulfilment and in this chapter the researcher argues that creativity should be supported in every school environment with a particular attention to less advantaged ones, where lack of resources and external *stimuli* are most common. Moreover, assuming that creativity is a skill that can and should be enhanced in students, as required by CfE, implies that the teachers should have a clear idea of what creativity is and how to develop a creative lesson. This result can be achieved only through teachers training on the various tools and techniques which can be used in the class, integrating it in the PGDE for students-teachers or organising courses within the school year for in-service ones. In this regard, the data showed in this study confirmed that the teachers do not have a full knowledge of the general characteristics of creativity (*i.e.* novelty, originality, usefulness and meaningfulness), but recognise them to various extent.

Furthermore, the data gathered highlighted the difficulties teachers experience in delivering a lesson developing interdisciplinary connections or using topics meaningful to students' lived experiences, which are considered to be useful tools in preparing a creative lesson. These issues resulted to be connected to CfE requirements in terms of number of topics to be delivered and assessments whose structure despite being planned by teachers is influenced by the need of preparing students to sit for the National assessments. The existing discrepancies in the curriculum which led teachers to a different teaching approach in the BGE phase with respect to the senior phase were inferred by crossing teachers' transcripts with literature and the analysis of CfE.

Despite the difficulties, teachers' constant efforts in implementing creativity by manipulating the curriculum for this purpose, using all the resources available, differentiating tests, and building up relationships with their students are remarkable.

The evidence of these constant efforts was gathered through the descriptions of their experiences in the class and the lesson plans collected, as due to the pandemic the access to schools was precluded.

Finally, a model was proposed to highlight the differences between the two teaching approaches contributing to creativity in school science, showing the connection of creative teaching with the main characteristics of a creative lesson (*i.e.* novelty and engagement) and teaching for creativity with the expression of creativity. Moreover, it underlined the role of self-confidence, in the expression of creativity and consequently in teaching for creativity and recognised in students' self-confidence the chance of expressing their creative skills.

Chapter 6. Conclusions

6.1 Overview

This study offered the chance to explore the approach of secondary school science teachers to creativity and creative teaching in the context of the Scottish education system. Furthermore, it allowed me to evaluate the issues teachers experience on a daily base in attending CfE's requirements.

Publications concerning creativity date back to 1889, and since then they increased exponentially to the extent that a quick search on the web would result in over 1.5 million papers related to it (Dimensions, 2022). Narrowing down such research to articles about creativity and education, this number falls to just over a million, and to slightly less than half a million if we focus on papers about creativity and secondary school. However, despite this huge number of papers, while developing my knowledge on creativity, I noticed the lack of a working definition of it. Consequently, I designed a definition that, with the support of the available literature, was meant to cover the four characteristics isolated (see **Chapter 2**, **Section 2.3**), *i. e.* novelty, originality, usefulness, and meaningfulness. I interviewed secondary school teachers and analysed their answers to direct questions (*'What does creative mean to you? Which is your idea of creativity?'*) looking for such characteristics (see **Table 4.5**) and used my working definition of creativity for a small-scale validation. Novelty and originality are concepts commonly recognised by laypeople when referring to creativity despite they are often acknowledged with a large-scale of meanings. Novelty is frequently mistaken for something new for everybody, instead a product might be novel even if it is new for the person who created it or new only to a certain extent. Similarly, originality is often confused with being eccentric or might even be associated to a number of psychopathologies such as schizophrenia, which is why its relationship with creativity must be confined within the boundaries of usefulness and meaningfulness. In this study, novelty and originality were clearly reported to be characteristics of creativity respectively by fourteen and thirteen teachers out of the twenty-one interviewed. However, usefulness and meaningfulness required a more structured analysis of the transcripts in order to be recognised as characteristics of creativity. In fact, an initial analysis resulted in eight teachers recognising creativity's usefulness and four its meaningfulness. Hence, it was carried out an in-depth analysis of the transcripts by evaluating the answers to questions related to the link between creative teaching and students' creativity enhancement (*'The CfE asks you clearly to enhance the creativity of your students. In which way do you meet this request? Do you have sufficient freedom or support to do that? Do you think that teaching in a creative way, enhances students' creative skills?'*). This investigation significantly increased the number of teachers recognizing useful and meaningful promoting creativity in school, as eighteen teachers acknowledged the importance of these two characteristics (see **Table 4.6**).

This research offered the chance of providing an overview on what a creative lesson is, following a path that led to design a definition which was presented to academics and teachers. This definition was built around the two concepts of novelty and engagement; the first was already described, whereas the second represents the in-depth involvement of students in the lesson, which goes beyond practical participation to it, but evolves in their interest in deepening the topics. Students' engagement in the lesson can be achieved through interdisciplinary connections and using topics meaningful to their lived experiences. To do that, teachers should be offered the chance of using a flexible curriculum, to access suitable resources, such as time, space, and money, to recur to active learning and to know their pupils. These requirements are fundamental to allow teachers to do their work in a creative way, *i.e.* teaching creatively. However, the data analysis and the supporting literature highlighted the performativity effect affecting teachers in the delivery of their work. They experience the pressure associated with a constant perception of lack of time and the responsibility of developing all the topics of an overloaded curriculum to guarantee their pupils to sit the National assessments. There is a clear discrepancy between what CfE requires from the teachers and what it offers to them. Teachers are required to enhance their students' creativity, but no instructions are provided to achieve this result. In contrast, clear guidelines are provided to teachers to prepare their students to sit exams, *i.e.* National 5, Higher and Advanced Higher, which are going to guarantee or preclude their students' access to the university. However, these assessments are not designed by the student's teachers but by an external commission, the Scottish Qualification Authority (SQA), who is going to mark them following parameters that are often not clear. The interviewees underlined the use of assessments that do not test skills but memorised knowledge and are written in a language that is often too difficult and not appropriate to the students' age. Teaching with creativity and enhancing student's creativity is achievable using interdisciplinary connections. However, this is only possible within the science disciplines, as meetings involving the teachers of the different disciplines are not scheduled during the school year. Therefore, designing an interdisciplinary curriculum is difficult to implement in practice.

The interviewed teachers highlighted these difficulties in delivering creative teaching, especially during the senior phase, although they make a constant effort in promoting creativity using all the resources available, differentiating assessments, and building up relationships with the students.

Creativity in school science is not limited to delivering a creative lesson, but involves teaching for creativity, *i.e.* teaching with the aim of enhancing students' creativity and this study pointed out that this is achievable when teachers and students are supported in their self-confidence. In this regard, teacher need to be supported in the effort to express their creativity by the school, the department and by their peers. In fact, an in-depth knowledge of the curriculum also contributes to enhancing teachers' self-confidence and results in mitigating the perception of lack of time associated with an inefficient time management, which in turn leave them more time to prepare and deliver a creative lesson. On the other hand, when considering students' self-confidence, it must be remembered that supporting it is not just a teachers' responsibility, but it concerns a number of environmental factors such as family, friends and generally speaking society. Notably, this is, at the best of my knowledge, the first study dealing with the relationship between creativity and students' self-confidence. The importance of self-confidence in kids and teenagers has been widely studied by scholars, and teachers are aware of their role in supporting them in developing it. Interestingly, only teachers working in deprived or mixed areas highlighted that creative students are self-confident. While I recognise that not all self-confident students are creative, my study underlines that self-confidence plays a major role in creative students allowing them to express their creativity without worrying about anyone's judgement and taking risks.

6.2 Limitations

When this project started (September 2018), I was supposed to contact the Glasgow city council to be allowed the access to secondary schools in the Glasgow area and meet science teachers willing to participate to this study. However, this research was developed in a difficult time, as the search for participants, interviews and data analysis occurred during the COVID-19 pandemic, which imposed several restrictions. In March 2020, schools were closed, and the council offices were hard to reach out due to the escalation of COVID-19 infections all over the country. The new situation risked jeopardizing the entire study and it was clear that a 'plan b' was necessary. With the support of my supervisor, Dr Jane Essex, I used the social media to reach teachers interested in my study. A snowball sampling approach was triggered by me posting an invitation on Twitter which was then shared by Dr Essex as well. This approach had undoubtedly some advantages. First, only teachers interested in creativity asked to participate to the study, which resulted in interviews that were enriched in ideas, suggestions, stimuli, and examples of creativity in the environment of the secondary schools in Scotland. On the other hand, I cannot exclude that this represented a limit of the study as well. In fact, teachers interested in creativity are more likely to acknowledge the importance of it, to attempt to deliver a creative lesson, to believe in the value of enhancing their students' creativity. The teachers could not be met in person of course, and interviews had to be carried out using online conferencing tools such as Zoom and Microsoft Teams. However, a large proportion of teachers who is not interested in creativity or believing that concepts and notions are the real backbone of an efficient education system may as well exist, but their ideas did not contribute to this study.

Since no travel to the schools was involved, this approach had the advantage that even teachers working in remote locations could participate to the study with the same ease of those working in Glasgow. However, online interviews also add some caveats, especially when considering the IPA approach used in this research. IPA relies on the researcher's (*e.g.* the interviewer) free interpretation of the ideas and experiences described by the interviewees. Such interpretation greatly benefits from the observation of the body language, such as gesticulation, crossed arms, avoiding eye contact, etc., that cannot be easily analysed on screen due to factors such as a close zoom on the face of the interviewee, background blearing, freezing due to slow internet connection. Moreover, many studies underlined how talking to a stranger on screen has a strong inhibitive effect on the capability of expressing freely and sincerely. In this regard, I believe that being a teacher myself played a positive role in helping the interviewed teachers to feel at ease.

The initial planned data gathering included the observation of teachers' lessons to understand the approaches they use to implement creativity in their everyday teaching activities. Such an action was of course precluded and replaced by the analysis of the teachers' lesson plans. Unfortunately, most of the teachers who participated to this study do not usually prepare lesson plans therefore, the number of lesson plans I could rely on was very limited. In fact, only four teachers out of twenty-one shared their lesson plans with me.

Another limitation to this study may be the small number of interviewed teachers. However, as repeatedly claimed in the previous chapters, defining it as a limit is at least arguable, as a researcher using the IPA can reach valuable conclusions upon analysing the ideas and experiences of even a single individual. In fact, this approach does not rely on calculating a statistical significance associated to the inference of an observed trend. However, the possibility that the pool of teachers included in this study is somehow biased cannot be excluded, because, as reported above, only teachers with a genuine interest in creativity decided to join the study. A geographical bias could also have influenced the result of this analysis as no teacher working in the central belt of Scotland participated to the study. However, the relatively large sample size used in this study (relatively to an expected IPA dataset) allowed to control for a number of other biases such as gender (11 women vs 10 men), school catchment area deprivation level (*e.g.* teachers working in areas labelled with a variety of SIMD – Scottish Index of Multiple Deprivation – were included in the study) and years of teaching experience (see **Table 3.2**).

6.3 Recommendations for future work

Creativity plays an important role in many fields such as economy (Edenson, 2010; Reader, 2006; Scottish Enterprise, 1999), science (McLeish, 2019), arts (Dutton & Krausz, 1981) and personal well-being (Eisenberger & Shanock, 2003; Sternberg & Kaufman, 2018; Weiner, 2000a), just to cite a few. Being considered such an important value in society, the ability to be creative is undoubtedly something to pursue. A fundamental assumption of this study is that creativity is an innate capability that can be supported, stimulated and enhanced at any stage of a person's life and CfE is in line with this idea as it urges teachers to help students developing their creative skills. However, despite CfE and society in general acknowledge the importance of creativity, no training on creative teaching is given within the PGDE course or during the teachers' career. This is in contrast with several studies demonstrating that teachers educated through creative teaching are more likely to use a creative approach to their work (Cropley, 2011; Davies et al., 2014; de Alencar, 1991). For this reason, I would recommend the development of training courses dealing with creativity in education and aiming the enhancement of the teachers' creative skills. Many resources are already available online that can help designing and delivering such courses. As a way of example, the Daydream Believers project (Daydream Believers, 2022) provides teachers with a bank of free resources to introduce creativity, critical thinking and problem solving into their learning space and also awards teachers with a qualification in creative thinking upon competition of their projects.

Many of the teachers interviewed talked about the difficulty associated with designing and delivering a creative lesson during the senior phase of the secondary school, when they must teach a multitude of concepts and notions to the students preparing to sit for the national assessments. In this regard, I would suggest a revision of the curriculum in terms of topics that are required to be taught, in an effort of reducing the impact of stressors such as the lack of time perception which clearly hinders the use of creativity in teaching. A reduced curriculum may go hand in hand with a revision of the national assessment system and the grading criteria, with more space left to questions aiming to evaluate the creative and critical thinking and the capability of problem solving.

Finally, in this thesis it was often highlighted how creativity can be enhanced by the use of interdisciplinary connections. This is undoubtedly a difficult task to achieve when no interaction at all is scheduled between teachers of different disciplines during the school year. In fact, very often different departments are even situated in different parts or floors of the school building. I would recommend scheduling meetings between teachers of different disciplines on a regular basis to bridge this gap. In my opinion, this action would have at least two positive effects. First, teachers of disciplines featuring common topics may find mutually beneficial to avoid any redundancy as doing so results in mitigation of the lack of time perception, and in more time to design novel teaching approaches. As a way of example, chemical kinetics is of course taught in chemistry, but it is also a topic that the students repeat in Biology when they study the enzymatic reactions. However, also teachers of apparently unrelated disciplines can find a common ground where interdisciplinary connections can be created. A chemistry teacher may relate the atom theory to the nuclear weapons used during the Second World War while a home economics teacher can explain the health risks associated with using different vegetable oils in terms of their content of unsaturated fats.

6.4 Next steps

The working definitions of creativity and creative lesson were tested within the limits of secondary school science teaching however, I designed them to be applicable to any discipline. Therefore, I would like to widen the sample of teachers to whom submit them and investigate whether different discipline teachers hold the same idea of creativity and creative teaching.

Furthermore, this study was developed within the context of the Scottish secondary schools and extending it to the other United Kingdom nations (or ideally to other countries) featuring different curricula and education systems would most certainly result in an interesting comparison.

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Appendices

Appendix A

SCHOOL OF EDUCATION

University of Strathclyde
Humanities & Social Sciences

2 June 2020

Dear Colleague,

My name is Maria Egizia De Pascale and I am a second year PhD student in Education with Dr Jane Essex and Dr Saima Salehjee at the University of Strathclyde. My research concerns the concept of creativity, creative science teaching, and the influence of the Curriculum for Excellence on the teachers' work.

In this time of my PhD, I should have been doing face to face semi-structured interviews to teachers and lesson observations, but due to pandemic, I could not start my data gathering.

However, I am now allowed to proceed online, and I am looking for science teachers willing to be interviewed via Zoom. I would be taking notes and, if they agree to, I would be recording the interviews. Furthermore, ideally, when people will be back to school, if the schools selected by the councils would be the same of the interviewed teachers, I would ask them the permission to attend to a couple of their lessons. The identity of the participants would be encrypted, remaining anonymous.

Thank you in advance for your help.

Kind regards,

Maria Egizia De Pascale

Appendix B

Consent Form C1 for science teachers of Glasgow' secondary schools that accepted to participate to the study on creativity and Science teaching approach at the time of the Curriculum for excellence

Name of department: Education

Title of the study: To what extent is science creative discipline, and how far is that reflected in the teaching *vs* the learning of science in Scotland?

- I confirm that I have read and understood the Participant Information Sheet for the above project and the researcher has answered any queries to my satisfaction.
- I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my personal information will be used and what will happen to it (*i.e.* how it will be stored and for how long).
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences. If I exercise my right to withdraw and I don't want my data to be used, any data which have been collected from me will be destroyed.
- I understand that I can request the withdrawal from the study of some personal information and that whenever possible researchers will comply with my request. This includes the following personal data:
    - audio recordings of interviews that identify me;
    - my personal information from transcripts.
- I understand that anonymised data (*i.e.* data that do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the research will remain confidential and no information that identifies me will be made publicly available.
- I consent to be a participant in the project.
- I consent to:

  ☐ Interviews

- ☐ Audio recording of the interviews
- ☐ All of the above

(PRINT NAME)	
Signature of Participant:	Date:

Appendix C

Participant Information Sheet for secondary school Science teachers, that have been nominated to help with the research on the relation between creative Science teaching and Curriculum for Excellence.

Name of department: Education
Title of the study: To what extent is science creative discipline, and how far is that reflected in the teaching *vs* the learning of science in Scotland?

Introduction
My name is Maria Egizia De Pascale, I am a full-time postgraduate student attending my second year of PhD in Education in the University of Strathclyde, and my supervisors are Dr Jane Essex and Dr Saima Salehjee.
I have eight years' experience as a science and mathematics teacher in secondary school. Besides the teaching of those subjects, along the years I have worked with many children,
This study will be used to understand the changes in Science teaching with respect to creativity since the introduction of Curriculum for Excellence.

What is the purpose of this research?
The aims of the study are:

1. To what extent science is a creative discipline;
2. To what extent the Curriculum for Excellence allows teachers to teach Science in a creative way;
3. How this is reflected in the teaching and learning of Science in Scotland.

Do you have to take part?
In accordance, with the Strathclyde Code of Practice on investigations involving human beings, you will be given and informed consent concerning your participation

to an online semi-structured interview, before data gathering commences. Your choice to participate will be safeguarded as much as possible. You will have two weeks to decide if to participate or not to the research, and you will be able to withdraw the collected data until they are not analysed. If the consent is not given there will be no consequences for you.

What will you do in the project?

This research will involve science teachers of Glasgow' secondary schools and you will be asked to take part in an individual interview. The interviews will be arranged taking into account your timetable not to affect your working time and conducted in your school.

If you permit me, I will record the interview and take notes. The recording is done not to miss any part of our conversation. The audio-recorded should take about 30 minutes.

Why have you been invited to take part?

You have been asked because you are a science teacher in Scotland whose experiences and ideas, I am interested in finding out about.

What are the potential risks to you in taking part?

It is not expected any risk to the physical or mental well-being of the participants, although the interview will require a little of your time.

What happens to the information in the project?

The information collected will only be seen by me and will be kept confidential from third parties.

You will be offered the chance to see the transcripts of the interviews.

All data will be kept confidential for the duration of the study, on completion of the report they will be safely stored on OneDrive, the University of Strathclyde recommended file-storage application. The data will be destroyed after 10 years.

The study's findings may also be presented at academic and professional conferences, published in academic journals.
The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data of participants will be processed following the provisions of the Data Protection Act 1998.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

If you are happy to be involved in the project, you will be asked to sign a consent form to confirm this. If you decide not to take part, thank-you for reading this information and considering my request. If you have any concerns or questions about the study and want to talk further about these, you can contact Dr Jane Essex or Dr Saima Salehjee (contacts details below).

Researcher/ Chief Investigator contact details:

PI: Dr Jane Essex
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Lord Hope Building
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Appendix D

Privacy Notice for Participants in Research Projects

Introduction
The University of Strathclyde is committed to transparency and to complying with its responsibilities under data protection legislation. This privacy notice sets out important information regarding how we use your information and your rights under the legislation. This privacy notice relates to individuals participating in research projects led by the University of Strathclyde. Please note that this standard information should be considered alongside information provided by the researcher for each project, which is usually in the form of a Participant Information Sheet (PIS). The PIS will include further details about how personal information is processed in the particular project, including: what data is being processed; how it is being stored; how long it will be retained for, and any other recipients of the personal information. It is usually given to participants before they decide whether or not they want to participate in the research.
Data controller and the data protection officer
The University of Strathclyde is the data controller under data protection legislation. This means that the University is responsible for how your personal data is used and for responding to any requests from you in relation to your personal data. Any enquiries regarding data protection should be made to the University's Data Protection Officer at dataprotection@strath.ac.uk.
Legal basis for processing your personal information
If you are participating in a research project, we may collect your personal information. The type of information that we collect will vary depending on the project. Our basis for collecting this information is outlined below:

Type of information Basis for processing

Personal information and associated research data collected for the purposes of conducting research.	It is necessary for the performance of a task carried out in the public interest.
Certain types of personal information such as information about an individual's race, ethnic origin, politics, religion, trade union membership, genetics, biometrics (where used for ID purposes), health, sex life, or sexual orientation are defined as 'Special Category' data under the legislation.	It is necessary for the performance of a task carried out in the public interest and It is necessary for scientific or historical research purposes in accordance with the relevant legislation (Data Protection Act 2018, Schedule 1, Part 1, Para 4).

Criminal conviction / offence data	It is necessary for the performance of a task carried out in the public interest and is processed in accordance with Article 10 of the General Data Protection Regulation and the Data Protection Act 2018, Schedule 1, Part 1, Para 4.

Details of transfers to third countries and safeguards
For some projects, personal information may be processed outside the EU. This will normally only be done when research is taking place in locations outside the EU. If this happens, the University will ensure that appropriate safeguards are in place. You will be fully informed about any transferring of data outside the EU and associated safeguards, usually in the Participant Information Sheet.
Sharing data

If data will be shared with other individuals or organizations, you will be advised of this in the PIS.

Retention of consent forms

If you participate in a research project, you may be asked to sign a participant consent form. Consent forms will typically be retained by the University for at least as long as the identifiable research data are retained. In most cases they will be retained for longer, the exact time frame will be determined by the need for access to this information in the unfortunate case of an unanticipated problem or a complaint. 5 years after the research is completed will be suitable for many projects, but beyond 20 years will be considered for any longitudinal or 'high risk' studies involving children, adults without capacity or a contentious research outcome.
Data subject rights
You have the right to: be informed about the collection and use of your personal data; to request access to the personal data we hold about you; you are entitled to request to have personal data rectified if it is inaccurate or incomplete; you have the right to request to object to your data being processed and you can request to restrict the processing of your personal information. To exercise these rights please contact dataprotection@strath.ac.uk. However, please note - in some research projects, it may **not be** possible to provide these rights because doing so would prevent or seriously impair the achievement of the research purpose. For instance, if you are participating in a focus group with multiple participants, if the research has progressed to a later stage of analysis, or findings have been published, it may not be possible to remove any one individual's personal data without having an adverse effect on the entire dataset.
Right to complain to supervisory authority
If you have any concerns/issues with the way the University has processed your personal data, you can contact the Data Protection Officer at dataprotection@strath.ac.uk. You also have the right to lodge a complaint against the University regarding data protection issues with the Information Commissioner's Office (https://ico.org.uk/concerns/)

Appendix E

Risk Assessment

ID: 1990: Semi-structured interviews to secondary school teachers and lessons observation

Section 1

1.1 Operation/ Activity

Location(s) of work

Lord Hope 530,

Description

I will be observing and interviewing teachers undertaking low risk activities, recording the interviews and taking notes. The interviews will be arranged on line considering the comfort and well-being of the participants as a priority, in a comfortable and private environment. I will attend to a science lesson and take notes, my presence will not involve any kind of work interruption or distraction for the teacher or for the students as the researcher will be there just as an observer, not interacting with students in any way.

1.2 Person responsible for this work

Jane Essex, Saima Salehjee

1.3 Person conducting assessment

Maria Egizia De Pascale

Section 2

Work Task Identification and Evaluation of Associated Risks

Interviews

Hazards Identified Stress caused to interviewees by discussion of their teaching.	**Who might be harmed and how?** Participants may experience distress.	**Existing Risk Control Measures** Questions will be posed in a way that is easy to respond and in a comfortable and private environment. In the event of distress, the interviews will be discontinued and/ or the interview questions that poses distress to the participant will not be probed further. Participants will have complete freedom to avoid any question.	**Likelihood:** 1:very unlikely **Severity:** 1:insignificant **Risk Rating:** low
Hazards Identified Breach of participants' confidentiality or loss of data.	**Who might be harmed and how?** Chief investigator/ research assistant and participants	**Existing Risk Control Measures** All data will be encoded to ensure confidentiality and stored securely. Participants will only be referenced according to pseudonyms	**Likelihood:** 1:very unlikely **Severity:** 1:insignificant **Risk Rating:** low

RA ID: 1990 06/05/2020 18:34:00 Page 1/3

Risk Assessment 1990

		and any personally identifying information will be edited out of research materials prior to be shared with others or reproduced in publications and related outcomes.	

Data Storage

Hazards Identified	**Who might be harmed and how?**	**Existing Risk Control Measures**	
Breach of confidentiality through unauthorized access to written field notes, recording of lesson and interviews, or loss of data.	The professional reputation of the researcher would be damaged, which could cause distress among teachers	Procedures for securing confidential data, including safe handling of recording and data encryption will be adhered to by the researcher. Recorders stored in locked filing cabinet. Key stored separately. Recordings downloaded from recorders regularly onto PC not connected to network or internet & password protected. Backed up to Strathcloud on daily basis.	**Likelihood:** 1:very unlikely **Severity:** 2:minor **Risk Rating:** low

Data Analysis

Hazards Identified	**Who might be harmed and how?**	**Existing Risk Control Measures**	
Breach of confidentiality through unauthorized access to direct quotes used to analyse the data or loss of data.	School teachers could experience distress. The professional reputation of the researcher would be damaged.	All data will be transcribed by the researcher and will be anonymized. Recordings will be destroyed when data processing is complete. Transcripts will be stored in a password protected and encrypted files on Strathcloud and held for 10 years following completion of study. Any printed copies of transcripts will be kept in a secure cupboard at work and will be destroyed after completion of the project.	**Likelihood:** 1:very unlikely **Severity:** 3:moderate **Risk Rating:** low

Section 3

Identified Actions to Improve Control of Unacceptable Risks

No unacceptable risks

Section 4

Significant Findings

Additional Information

Risk Assessment 1990

Section 5: Signatories

Name	Signed
Jane Essex	
Saima Salehjee	
Maria Egizia De Pascale	15/01/20
Shagufta Anwar	
Shagufta Anwar	
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Shagufta Anwar	
Maria Egizia De Pascale	20/01/20
Maria Egizia De Pascale	18/02/20
Maria Egizia De Pascale	06/05/20

Appendix F

Data Management Plan

Project Name:	To what extent is science a creative discipline, and how far is that reflected in the teaching and learning of science in Scotland?	Funder:	None
Project Description:	In accordance with the Covid-19 policy, the data gathering of my research project involves online semi-structured interviews to secondary school science teachers of all around Scotland and the analysis of their lesson plans. The number of teachers involved will be from a minimum of 15 to a maximum of 20. This research will have a qualitative connotation based on the experience of professionals, where the variety of the sample, with teachers coming from the mainstream schools, will offer a glimpse of the problematics that the teachers are facing in this time of the Scottish educational system.		
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1. **Data Collection**
What data will you collect or create?

Use the table below to list all research data that you will collect or generate as part of this project. Examples have been included to help you get started.

Data type	Original format	Preservation format*	Estimated volume	IPR Owner	Active storage location	Completed storage location
Recorded Notes	audio	Original	~ 5 GB	UoS	Onedrive	Onedrive
Trascription Files	.xlsx, .docx	Original	~ 3 GB	UoS	Onedrive	Onedrive
Paper notebook	Paper	PDF	~ 400MB	UoS	Cabinet in dept	Onedrive
Lesson plans	.docx, .pdf	PDF	~ 1 GB	UoS	Onedrive	Onedrive

How will the data be collected or created?

The data will be collected *via* authorised recording, transcript of the recorded material, and paper hand notes.

2. Documentation and Metadata

What documentation and metadata will accompany the data?

The teachers will be invited to participate in online semi-structured interviews and, with their permission, to record their interviews to make the data gathering more accurate.

The interview data will be investigated through the interpretative phenomenological analysis (IPA). IPA is a qualitative research method, based on the interpretation of an individual meaning-making of a certain experience (phenomenon) (Alase, 2017; Cooper et al., 2012; Denovan & Macaskill, 2013; Farmer & West, 2019; Finlay, 2014; Hefferon & Gil-Rodriguez, 2011; Jeong & Othman, 2016; Larkin et al., 2006; Miller et al., 2018; Newberry, 2011; Rodham et al., 2015; Smith, 2004, 2011, 2018; Smith et al., 2009b; Smith et al., 1999; Smith & Osborn, 2008b; Symeonides & Childs, 2015; Tuffour, 2017; Vicary et al., 2017). This technique is clearly double interpretative, as it is an interpretation of another person interpretation. Therefore, the interpretative phenomenological analysis is phenomenological, but also interpretative, and idiographic, as it focuses on the detailed study of a specific case. In the interpretative phenomenological analysis, the subjective truth outweighs the objective one, as the participant is considered an expert of the phenomenon under study.

3. Ethics and Legal Compliance

How will you manage any ethical issues?

My research project involves online semi-structured interviews to secondary school Science teachers of all around Scotland and the analysis of their lesson plans.

The considered ethical issues are:

- Consent/ Use of digital media – protecting data and identities

In accordance with the Covid-19 policy, the teachers will be invited to participate in online semi-structured interviews and, with their permission, to record their interviews to make the data gathering more accurate. Furthermore, the teachers will be also asked to share a couple of their lesson plans

In accordance with the Data Protection Act 2018 and the General Data Protection Regulation on investigations involving human beings, they will be given an informed consent form concerning the semi-structured interview, before data gathering commences. They will maintain the right to access to the data stored concerning them and to request the destruction or the withdrawal of their data. Furthermore, they will be offered the chance to see the transcripts of the interviews. In any case the major concern will be protecting participants' reputation from damage. The transparency and openness of the research are embodied in the process, as the interviewed teachers will be informed of the purpose of the research and the findings will be shared at the end. The email addresses of the participants will be collected and stored safely, as a summary report will be sent via email to the participants.

- Privacy: anonymity and confidentiality

The confidentiality and privacy of the participants will be guaranteed by pseudo-anonymization, associating specific codes to them that will enable the identification of subjects and storing the said codes and the collected data in OneDrive. It will not be possible to identify the participants in the investigation output. The semi-structured interviews will be carried on online and the audio recording will be anonymised.

- Bias

The questions have been designed then scrutinised by my supervisors to avoid them being leading or indicating any researcher bias.

Furthermore, the research is connected to a new definition of creativity and creative lesson, supported by literature, that will be shared with the participant teachers, to verify the observations collected. The researcher in charge of the semi-structured interviews is a Science teacher in the secondary school, this might be looked at as being a bias as the interviewer could be considered an insider researcher, that is why the data collected (transcription of the semi-structured interviews) will be analysed from the perspective of a definition of creativity. Moreover, the participant teachers will not be Science teachers of the secondary school attended by the daughter of the researcher to avoid any conflict of interest.

- Coercion and power relationship

There will not be any power relation involved, as the teachers will choose to participate or not, beside there will be no coercion and no cover recording. The participant teachers will have two weeks to decide if to participate or not to the research, and they will be able to withdraw the collected data within 4 weeks after the interview before the interviewer processes the transcripts (see Appendix 1).

- Distress in sensitive topics or during a stressful period

Semi-structured interviews will be arranged taking into account the timetable of each teacher not to affect their working time. Actually, they will decide when the semi-structured interview can be conducted and if sharing their lesson plans.

Although the involved individuals are adults in a specific working category, the interviews will be arranged considering the comfort and well-being of the participants as a priority, and as far as possible in a comfortable and private environment. There will not be additional risk to the physical or mental well-being of the participants.

- Backyard/ insider research

It will not be involved any backyard or insider research in the study.

How will you manage copyright and IPR issues?

The confidentiality and privacy of the participants will be guaranteed by pseudo-anonymization, associating specific codes to them that will enable the identification of subjects and storing the said codes and the collected data in OneDrive. It will not be possible to identify the participants in the investigation output. The semi-structured interviews will be carried online and the audio recording will be anonymised.

The participants will maintain the right to access to the data stored concerning them and to request the destruction or the withdrawal of their data. Furthermore, they will be offered the chance to see the transcripts of the interviews. In any case the major concern will be protecting participants' reputation from damage. The transparency and openness of the research are embodied in the process, as the interviewed teachers will be informed of the purpose of the research and the findings will be shared at the end. The email addresses of the participants will be collected and stored safely, as a summary report will be sent via email to the participants.

The information collected will only be seen by me and will be kept confidential from third parties.

The data will be kept confidential for the duration of the study, on completion of the report they will be safely stored on OneDrive, the University of Strathclyde recommended file-storage application. The data will be destroyed after 10 years.

The study's findings may also be presented at academic and professional conferences, published in academic journals.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data of participants will be processed following the provisions of the Data Protection Act 1998.

4. Storage and Backup

How will the data be stored during research, and how will you manage access and security?

Electronic data (Word, Excel documents, audio recording) will be store on OneDrive, while paper data will be stored in a personal cabinet in the department. The access will be guarantee to members of the research group previous communication to the researcher.

5. Responsibilities and Resources

Who is responsible for data management?

My supervisors and I are responsible for implementing the plan and ensuring it is revised and reviewed. The same people will be responsible for each data management activity.

What resources will you require to deliver your plan?

It will not be required any additional hardware or software beyond the existing institutional provision.

Appendix G

Semi-structured interview questions

1. How long have you been teaching science? Do you have teaching experience in different types of school (selective, ASN, residential, private)?

2. What kind of work experience did you have before starting to teach, including any voluntary roles? (previous job experience, if any)

3. Do you feel any pressure or constraint upon how you deal with the Curriculum for Excellence (CfE)?

4. It is 10 years that the CfE was introduced. Do you think that it affected your teaching style? Or the way you used to plan your lessons? And if so, in which ways?

5. Do you think that the current national assessments provide a good measure of students' learning?

6. Are the assessments you use according to the CfE in the broad general education phase very different from the one you use to prepare students for Nat-4 and Nat-5? If yes, can you explain why it is?

7. The CfE states that students need to be considered in a more holistic way, that is in terms of their personal attributes, as well as taking account of their background. Do you think that the CfE gives you enough freedom to do that?

8. What does creative mean to you? Which is your idea of creativity? What do you think creativity means, or looks like, to your students?

9. What personal trait do you associate with student you teach who is creative? Describe the profile of a typical creative student (*e.g.* extrovert, highly organised, self-assured)

10. The CfE asks you clearly to teach in a way that would enhance the creativity of your students. In which ways do you meet this request? Do you think you have sufficient freedom or support to do it?

11. Do you prefer to pose your students open-ended problems or multiple-choice questions? Which questions do you think are more useful with respect to the development of creative thinking?

Appendix H

Spearman correlation

Calculating the correlation between two variables means to investigate whether they co-variate. When both variables increase concordantly, they are said to be positively correlated. As a way of example, the book weight and the number of pages are positively correlated, as books with higher number of pages are expected to weight more and *vice versa*. On the other hand, if one variable decrease when the other increases, they are said to be negatively correlated. One example of negative correlation is that between vaccination rate and hospital admissions. In my study I wanted to study the correlation between the SIMD (Scottish Index of Multiple Deprivation) and the perception of the interviewed teachers about the area served by the school they teach in. There are several methods that can be used to investigate whether two variables are correlated and can be divide into parametric and not-parametric methods. The former is generally used when the studied variables are distributed according to a normal distribution (*e.g.* a symmetrical bell shaped distribution with the maximum value being represented by the mean and the width being determined by the standard deviation), whereas the not-parametric methods are used when this assumption cannot be done. Due to the low number of interviewed teachers and the few possible values for both the SIMD and the area perception, I could not assume that these two variables were normally distributed and for this reason I decided to use a not-parametric approach.

One of the most used non-parametric methods to study the co-variation of two variables is the Spearman correlation. With this approach, we do not study the covariation between the variables directly but rather that of their rankings. Briefly, for each variable, the values are sorted and a pre-ranking value is assigned by giving the value of 1 to the first in the list, 2 to the second and so on. Then A final rank is calculated by averaging the pre-rank values corresponding to the same original value. **Table H.1** shows the application of this approach to the teachers' perception of the school area. Five teachers reported a value of 2 and for them the pre-ranking values in the sorted table were 4,5,6,7 and 8. Therefore, the final rank value for these interviewees was transformed in the corresponding average (*e.g.* 6). In **Table H.2**, the result of this approach is presented for the SIMD values.

Table H.1. Ranking approach for (a) the teachers' perception of the school area and (b) the SIM

(A)

(Pseudonym)	Teacher perception value	Teacher perception pre-rank	Teacher perception rank
1. Anya	2	4	6
10. Jamie	1	1	2
11. Laila	2	8	6
12. Karol	2.5	9	10
13. Jerome	2.5	10	10
14. Jacob	1	2	2
15. Alan	3	14	14
16. Carter	3	15	14
17. Joan	3	16	14
18. Sandra	5	20	20
19. Arthur	1	3	2
2. Rachel	2	5	6
20. Harriet	2.5	11	10
3. Laura	2	6	6
4. Timothy	3	12	14
5. Eloise	2	7	6
6. Darren	4	17	18
7. Simone	4	18	18
8. Mark	4	19	18
9. Laureen	3	13	14

(B)

(Pseudonym)	SIMD	SIMD pre-rank	SIMD rank
4. Timothy	1	1	1.5
10. Jamie	1	2	1.5
3. Laura	3	3	4
9. Laureen	3	4	4
16. Carter	3	5	4
2. Rachel	4	6	6.5
17. Joan	4	7	6.5
13. Jerome	5	8	8.5
20. Harriet	5	9	8.5
1. Anya	6	10	12.5
5. Eloise	6	11	12.5
6. Darren	6	12	12.5
11. Laila	6	13	12.5
14. Jacob	6	14	12.5
19. Arthur	6	15	12.5
7. Simone	7	16	17
15. Alan	7	17	17
18. Sandra	7	18	17
8. Mark	9	19	19.5
12. Karol	9	20	20

The rank values for the two variables are then joined and the difference d between them calculated (**Table H.2**).

Table H.2. Associated rank values of teachers' perception of school areas and SIMD

(Pseudonym)	Teacher perception rank	SIMD rank	d
1. Anya	6	12.5	-6.5
10. Jamie	2	1.5	0.5
11. Laila	6	12.5	-6.5
12. Karol	10	20	-10
13. Jerome	10	8.5	1.5
14. Jacob	2	12.5	-10.5
15. Alan	14	17	-3
16. Carter	14	4	10
17. Joan	14	6.5	7.5
18. Sandra	20	17	3
19. Arthur	2	12.5	-10.5
2. Rachel	6	6.5	-0.5
20. Harriet	10	8.5	1.5
3. Laura	6	4	2
4. Timothy	14	1.5	12.5
5. Eloise	6	12.5	-6.5
6. Darren	18	12.5	5.5
7. Simone	18	17	1
8. Mark	18	19.5	-1.5
9. Laureen	14	4	10

The Spearman rank correlation Rs is then calculated by using the following equation:

$$Rs = 1 - \left(\frac{6 \sum d^2}{n^3 - n} \right)$$

Where the n is the number of observations (*e.g.* 20 that is the number of interviewed teachers). The Spearman correlation can be positive or negative, depending on direction of the co-variation. Its absolute value is comprised between 0 and 1, with the former implicating no correlation at all and the latter being indicative of a perfect correlation between the two variables. The Spearman correlation is associated to a significancy (p-)value that deals with the probability that the correlation is a chance result. This value is comprised between 0 and 1, being indicative of no or max probability for the observation to be due to chance respectively. Generally, a p-value less than 0.05 is considered indicative of a significant correlation (*e.g.* the probability of being wrong when claiming that there is correlation between two variables is less than 5%).

Appendix I

A selection of three interviews

Legenda.

(.)	Short pause (~ 0.3 sec.)
(..)	Medium pause (~ 0.6 sec.)
(…)	Long pause (~ 1 sec.)

Jamie, Chemistry teacher, 3 years of experience

Interview length: 52’20” Interviewed in June 2020

EDP: How long have you been teaching science?

Jamie: So, I’ve been teaching for three years, now. So not, not very long. [laughing shyly]

EDP: It’s fine. It’s absolutely fine.
Every experience counts.
Have you had different school experiences in these 3 years? I mean, in different type of school, like selective or additional support needs ones, or private?

Jamie: No, I’ve always been in the state school sector.
I’ve only been, I’ve been in one school for the three years.
So, I don’t have experience of another school, I have only got that one experience, as have been in one school.

EDP: Where is it? in which area is this school?

Jamie: It’s in Easterhouse, in the East End of Glasgow.

EDP: Okay. Is it an area (..), how can I say (..),

Jamie: It's an area of high deprivation as about 80% of our young pupils come from SIMD 1 and 2, so, the bottom 20% of postcodes in terms of deprivation, we have a lot of our kids coming from areas of (..) high deprivation.
So, they experience the socio-economic impact of education.
So, I suppose, in a sense, as a result of that, in maybe indirect way, as a result of that, we have to really think about how we are planning our courses and think about how we deliver the courses to try and engage the young people, who may be disengaged with that education otherwise, and because of that doesn't worth their own control.
And so, that's why I was quite interested and keen to be a participant for you, because I think that the young people that I teach are very unique in terms of the school community,
and much of our work is very unique in having such a high concentration of deprivation.

EDP: Do you come from, I mean, I'm not asking like a personal information, I'm asking to understand how much do you know that area, do you come from that area?

Jamie: Yeah. Yeah. I do. So, I am, I grew, I grew up in the area, but I didn't attend that school, I attended a school nearby which is a much bigger school, like a traditional comprehensive secondary with a bigger variation in needs.
I know the area very well. So, I think that's why I've stuck around, as well. [laughing shyly]

EDP: Ok. The next question is, what kind of work experience did you have before starting to teach? If you had any, like also any voluntary roles, or any previous job experience.

Jamie: When I was a student at Strathclyde University doing my undergraduate degree, I worked as well.

I volunteered as a STEM ambassador, through the University of Glasgow, that actually run the program, and that got me a sort of experience of meeting and building a network of STEM professionals, working in their own respective industries, and who shared their experiences, and then I was in a better position to go into the schools.
So, although I was taking only my science experience from university, I was able to sort of work with a network of industry people who came, who also supported, as well.
So, I went out to schools with those members of the STEM industries to deliver some activities to young people.
And also, when I was in my final year, during my undergraduate degree, I actually undertook paid employment with the University of Strathclyde, while working with the awaited access team, who led us to secondary school pupils, again trying to encourage them to consider, specifically consider chemistry, as a career option for them.
But I don't have industry experience of working as a chemist.
I very much come from education and stayed that way.

EDP: Yes, but, in fact, the question concerns whichever experience, as I said, also experiences as volunteer.
And, so you are quite fresh to the Curriculum for Excellence.

Jamie: Yeah.

EDP: And did you finish the secondary school more or less than 10 years ago?

Jamie: Okay, it would have been just less than 10 years, about 8 years ago.

EDP: Because the Curriculum for Excellence was introduced in the last 10 years, no?

Jamie: Yeah, yeah.

EDP: So, you experienced (.)

Jamie: Yeah. I had, I think I was one of the, sort of, I was at school during that transition period, and so (..) we had experienced the old one in the 5 to 14 curriculum, which existed a bit prior to the Curriculum for Excellence.
And then, as we moved into the senior phase, like (.) when we started, when we had done our Highers (.), I think that was the first year of the new CfE Higher (..) we had a sort of blended experience.

EDP: It's great, because you have both the experience as a student, and also as a teacher.
The following question is: do you feel any pressure or constrain upon how you deal with the Curriculum for Excellence? The question is reasonable at this stage.

Jamie: [laughing] I think it's one of those questions that I would say yes and no.
And I would say that, as a teacher, there's no doubt that there are pressures involved especially in the science curriculum.
And I would say, for the S1 to S3 people in the broad general education, their experiences and outcomes are packed full of content, that we feel pressure to get through.
And I suppose that pressure come, because, you know, you have to address the content to set them up well for their senior phase experiences, and for when they move on to studying for their exams.
Saying that it's something that end discussion with other teachers at the school, who aren't science teachers, as they don't seem to have that same level of content that they have to get through.

But then again, when you read all of the Curriculum for Excellence guidance documents,
they make it clear that you don't have to cover each and every experience in the outcome within it (.).
So, as a teacher, you're torn.
Do you focus on giving the young people that depth of experience, or do you try and give them the breadth of experience?
And, and that's where the challenge, the main challenge is in the Broad General Education for pupils come, I think.
But, in saying that, there's a lot of flexibility within the curriculum, as I feel I still have access in school to the old 5 to 14 curriculum.
And when I look back, I can actually, remember the worksheet.
They've not changed at all.
And I remember it was extremely prescriptive the old 4 to 14 curriculum from my point of view.
So, the CfE definitely provides teachers with more flexibility, but with that flexibility, I think come constraints ironically, because you are under pressure to cover as many of the experiences and outcomes that you can.

EDP: Do you think in some way it affects your teaching style? Or the way you plan your lesson and, if so, in which way do you think it affects you?

Jamie: So, I think that it does definitely impact on the way that you plan your lessons.
And I think that the guidance documents, when they were first introduced years ago, and that is me talking from looking through the old documents, weren't clear at all and they were quite ambiguous about what was expected.
Whereas, now there are benchmarks and so you know exactly what you're trying to get the young people to achieve.

So, so with the inclusion of the benchmarks now it's much easier to plan your lessons, knowing that is ultimately what you're wanting to the young people to be able to do in terms of planning your lessons (.)
There are so many parts of the science curriculum that would lead to interdisciplinary learning and working in cross-curricular, but, again, timetable constraints within the school make that almost impossible to achieve a lot of the time, which is really frustrating, because I know how important is.
I know how important is to the people, to the people who designed the Curriculum for Excellence.
It was a fundamental part of the curriculum, but it's something that, I would say personally, I can't speak for other school, but for the school I teach in is almost impossible to do with the timetable in its current form.

EDP: Do you think that the current National assessments provide a good measure of the student learning?

Jamie: I think that it's a really difficult question to answer, isn't it?
And I feel like overall, they don't provide a good representation of the young pupils learning in terms of the assessments.
I would say definitely not, on balance, but the difficulty comes again, and what I think, what happens in the first and third year of courses in the Broad General Education, you are very much encouraged and supported by the curriculum to assess pupils in various ways.
It's not, it's not set down in formal assessments, although that does form quite an important part of the assessments and you also consider their practical work, but you can set other contributions to class discussions.
There are written work, there can be the presentations, and is a very holistic approach to assessments as soon as they get into fourth year.
Although, that goes out the window because you're working towards big final exam in the summer, and that's where those young people who have excelled in the first

and third year with the holistic approach to assessment, many of them, particularly many of them in the community that I teach in, struggle with the aspect of working towards one final large piece of assessment that's written.

And it seems very unfortunate as the curriculum seems geared towards giving everyone the most appropriate (.), because it gives the teacher flexibility in first and third year to assess pupils in the way in which you feel they will, they will go best with.

And, obviously, as a department in the school, we moderate our assessments and standardized them.

So, it's not like we are changing the assessment in order for kids to (..), we're not trying to manufacture them, but you're trying to give them the best possible chance, whereas you don't have that flexibility when it comes to fourth, fifth, and sixth year that's the skill window for the National 5, the Highers and Advanced Highers.

And so, first and third year, yes, possibly, fourth, fifth and sixth year, no.

EDP: Actually, the next question is strongly connected to the answers you are giving me.

Are the assessments you use according to the Curriculum for Excellence in the Broad General Education phase very different from the ones you use to prepare students for the National 4, National 5? and if yes, why?

Jamie: And yes, it's very different and as I was saying previously, it's very different, because of that holistic approach, you can take in first and third year.

Of course, there's nothing stopping teachers taking the holistic approach throughout fourth, fifth and sixth year as well, but you also have a responsibility to prepare the young people for their final exam, to make sure that they're equipped with the confidence in their skills to approach the exam paper and do as well as they can.

So, you feel the pressure as a teacher when it comes to the National qualifications to take a different approach to assessment, I would say, and it's very much doubt to

keep the interest of the young people at the core, because you're trying to prepare them as best as you can for that final exam, but it's very different.
I would say, I would say that we still use the holistic view for tracking progress.
We still use it in throughout the year, but when it comes to the assessments, and ultimately especially this year in this situation that we're in with the school closures and the exams not going ahead all these holistic pieces of evidence are important.
But at the end of the day, you need to have that hard evidence of the unit assessment tests that are done under the exam conditions.
You need to have preliminary exams that are done on the curriculum conditions.
And so, the focus very much shifts on to a formal assessment, and written assessments.

EDP: Did you observe lot of students, leaving the school at 16 in your community? I mean, when they are 16 in S4. Is it a high percentage?

Jamie: Ahem, I think that there's more and more, there's more and more who are choosing to stay in now.
I think that is for some of them, for the majority of them, it's because they want to continue with their formal education.
They need the qualifications in the workplace or for their studies, but for some of them, as well, and I would say for, for many of them, at the school that I teach, the reason that they stay on is because they lack the confidence to leave.
They want to leave.
They want to go and work.
They want to contribute to their homelife.
They know their parents may be struggling, they know that they need to go and earn money, but they lack the confidence to do that so, they are choosing to stay on as well.
And so, I would say especially in schools like the one that I teach, your, your senior phase pupils are not necessarily made up that core group that still want to be there.

They feel like they have to be there for various reasons.

EDP: Do you think that the students that decide to leave, do that for social reasons, rather than due to this change from the Broad General Education to the Senior phase?
I mean, it's not a matter of not feeling not ready, but a social problem?

Jamie: Okay, I would say, I'd say that it's reasonable to say, and, of course, that's a huge generalization to me, but that must have an impact.
The transition from the Broad General Education to the Senior phase must have an impact on some of their experiences.
I know for certain that some of the young people that I have taught, have struggled with National qualifications, and struggled with the exams and that would be their main drive to leave school, because they don't want to have to sit like in exams.
But I think that for my specific circumstance, this specific circumstances at school, I think that they're choosing to stay on for social reasons.

EDP: Alright. You use the word holistic that it's perfect for the next question.
The Curriculum for Excellence states that the students need to be considered in a more holistic way, and that's in terms of the person attributes as well as considering their background.
Do you think that the Curriculum for Excellence give you enough freedom to do that? to consider your student in a holistic way?

Jamie: Yes, the curriculum itself does.
In an ideal situation, you would have the opportunities to carry out like varied forms of assessment, that really captures the progress of young people and the achievements of young people.
And it's been so clear as a practitioner, that is the way that the curriculum has been designed, and it's very clear that that's the expectation.

I know that for every member of staff and the department I'm working in, we try our best to ensure that we have different forms of assessment that are being used, we also have an assessment impact for every young person, that's from first to third year they know every year what's the parts of assessment evidence that we require from them.

But, when the day-to-day reality of teaching cuts in, sometimes the easier option is to revert to the traditional forms of assessment, I would say, because when you're working with a group of young people who lack a lot of confidence, sometimes their preferred option would be, in my experience, to work independently, because they don't want to appear like they don't know what they're doing.

And so, they would rather work independently on pieces of assessment that is only going to be seen by the teacher.

They don't want to participate in presentations, at least a lot of them.

A lot of them lack confidence when it comes to practical skills, and I think that what we have tried to do is not use the word *assessment* when it comes to things like assess in practical skills.

We use *observing*.

Every day, a lot of our assessment is just observation and seeing how the young people interact with each other, how would they answer questions in class, participate in class discussions, and how do they work with their peers and completing practical.

But I think that is difficult.

EDP: What does creative means to you? and which is your idea of creativity?

Jamie: Okay. I suppose creativity, I mean, scientists need to be creative.

It is part of our overall nature, I think.

As a scientist, you have to be creative in your approach to problems, and to me, creativity is all about the same cliché: thinking outside the box to solve maybe problems, trying to be innovative in your approach to things.

As a teacher, employing versatile teaching methods as part of creativity, I would say, and I guess ultimately, creativity needs to be integrated to your practice as a teacher. Especially when you're trying to achieve the aims of the Curriculum for Excellence.

EDP: And what do you think that is the idea of creativity of your students?

Jamie: So, what's their idea of creativity?

EDP: Yes, what do you think is creative to them?

Jamie: So, I think if you were to ask the young people I teach what creative means, they would think that's going into the art classroom and painting.

I don't think that they would necessarily link science to creativity and I think that that's because they're used to being told, and that there are probably a lot of them used to being told,

'This is what we're doing today. That is what you're going to learn. That is the experiment, you're going to do. I'm going to show you what you're doing, and then you're going to go and do it yourself'.

And so, possibly, a lot of the young people in my experience, when I've been speaking to them about their previous experiences of science, probably they don't see it as being particularly creative as a subject, because they don't have the freedom. They don't have the flexibility in themselves a lot of the time and I think that largely comes down to a lack of resources, when it comes to doing practical work.

I think that it's probably due to those experiences from primary school, when they've been learning science at primary school.

We are doing a lot of work as a school trying to deliver science in a more creative way, but I think that because of their previous experience, they wouldn't consider science a creative subject.

EDP: I am sending you now via chat, a definition of creative lesson and I would like to know what you think about it.

Jamie: [Once read] Yeah, I would definitely agree. I would agree with that.
I would say that I agree straight away.
What comes out to me is that I'm trying to develop their understanding of the subject under study in a novel way and I think that is fundamental to creative teaching and learning and, I suppose, as I've mentioned previously, the interdisciplinary connections.

EDP: I wrote this definition and I tried to write it down as much general as it can, to cover all the possibility. So, it's not necessary for the lesson to be interdisciplinary, but there is the need of engaging.
So, which way would do you use when you teach? Which part of this definition do you use?

Jamie: I would say that probably the most used part is trying to use versatile techniques in terms of what's in use of the novel approaches and using topics that are meaningful to students' lived experiences.
I've found that very difficult, but it's not something that we haven't done.
I can tell you about some interdisciplinary connections that we have done, I have made, but that's something that, maybe, happens one week of the year, when we've been given some time on the timetable to do it, but I would say that certainly that approaching things in the study in a novel way and take the topic to the real world is certainly what I try to do in my teaching.

EDP: In the Curriculum for Excellence, it is written that, as a teacher, you have to be creative in proposing your discipline, your topics, but, at the same time, you have to enhance the creative skill of the students, and so there is this big question in my mind.

And I'm asking everybody what they think about it as I don't have a proper answer yet and the question is: do you think while doing a creative lesson you enhance the creative skills of the students? Do you think there is a connection?
Because sometimes I can see it sometimes I cannot.

Jamie: I think that (..), it very much depends on the group that you have in front of you.
I believe it very much depends on that.
In my experience, certainly, when you're teaching, and when we're relating it to students lived experiences, bringing in view world aspects of what they're learning, I think, equips the pupils with the ability to then continue to make connections.
I think you have to make the initial connection sometimes for the young people, and maybe once you've done, once you've enabled them to access that for themselves, I think that some pupils, some young people, will do that by themselves.
But I think, for me, for the majority of the young people that I think about or might have just known, I need to be the one that enables them, but as soon as they've been enabled, and I think it's so important, once you've made that connection for them, they are able then to do for themselves.
And, ultimately, what I would hope as a teacher is that they're able to continue to be independent in themselves, in making connections as they go on, and also across their other subjects.
So, in terms of that, I think that if I think about approaching things in a novel way and if I think about lessons that we've done, we really tried the context-based learning project, or we've tried to even use debates and dramas.
And I think that that has been really good allowing the young people to, enabling them to make the connections.
This is, this is how they are learning.
This is what we are still learning here.
It may not feel like the traditional way of learning, but we're still learning.
So, exactly, it's a very difficult question and such an interesting question.

EDP: Yes, that's why I'm asking it to everybody, it's a question that I have been thinking, on and on.
Talking about students, do you think that there is a personality trait that you associate with the students you teach who are creative? How would you describe the profile of a typical creative student? For example, extroverted or not, highly organised or not.

Jamie: Yes, so, if I think of it in my head, there are one or two (pupils) who would stick out, who are being particularly creative, and I wouldn't say necessarily extroverted.
I would say that quite often are quietly confident in their own abilities.
But then I would say, probably, the most creative student I've ever taught, certainly, was not an extrovert, but very eager to learn, hardworking, asks many questions and tends to be, huge generalization, tends to be female, I would say.

EDP: That's a good answer.
[both laughing]

Jamie: And (..) I think it's someone who has, I would say, widen varied interests.
I would say someone who's creative, as I am thinking, it's not someone who you would necessarily see as that person as in traditional three science person and math.
I think that's someone who has appreciation and knowledge of the world where we actually live in.
I think that's so important and enabling someone to be creative.
If that makes sense, does that make sense?

EDP: Yes, it does. I was smiling when you talked about female students being creative, because there are many projects around the world that intend to get them close to science, as many girls usually quit the science disciplines, you know.

Jamie: Yeah, yeah.

EDP: So, your point of view as science teacher is nice to hear because I think it might be maybe a sign of the fact that they are not quitting as much as they used to, you know.

Jamie: Yeah, and I think that I agree.
I think that there's so many more girls who are choosing to continue their science studies, but I also wonder if it's a perceived lack of creativity in science that puts them off continuing study.
That's just me, I'm thinking.

EDP: No, no, it's an interesting point. Absolutely.
The Curriculum for Excellence asks you to teach in a way that would enhance the creativity of your students. Do you think you meet this request in any way? and in which way? and do you have a sufficient freedom to support creativity?
It's very much connected to what we have said before about the Curriculum for Excellence. But do you think you are supported in this?

Jamie: Yes, I think, as we said the Curriculum for Excellence, compared to the previous curriculum, certainly, supports you in approaching the teaching of science in a creative way.
And I think that, possibly, teachers who are new to the profession, are maybe more equipped than those who have been teaching for a long time in some ways.
And the only reason that I say that is based on my own experience, but that's a very big generalization, and I wouldn't want to offend anyone by saying that, because I know that many, many, many experienced teachers are very creative in their approaches.
I just don't see that for myself sometimes.

I think that, certainly, more and more there's a huge focus on developing the young workforce in Scotland.
Like that's a huge focus and is part of the Curriculum for Excellence.
I think that maybe inadvertently in trying to attract that part of teachers being creative,
other been forced to be creative in that respect.
By bringing in careers, you're bringing in people who work in the industry and linking it to different career option.
And so, I think that leads to many teachers probably being creative, and they don't realize it.
I think that resources, resources in school are certainly something about it, because I think that some people would think that being creative means that you have to have an all singing and all dancing lesson, and many teachers will be very creative.
And that's where, maybe, I've been really unfair, actually in what I said that there are more experienced teacher being less creative.
Actually, I take that back.
Because, I think, I think that they're probably being very creative without necessarily realizing it, going by the definition of the creative teaching.

EDP: So, the next one is our last question. I kept you more than half an hour.

Jamie: Don't worry.

EDP: Do you prefer to pose your student open-ended problems, or multiple-choice question? and which question do you think are more useful with respect to the development of creative thinking?

Jamie: I would say (.), so, I think the approach (.), the approach depends on the stage of the young people, I think.

It’s so hard, because (..) I’ll tell you why I’m finding that quite hard, and you’ll understand that yourself.
When the pupils come on to their National qualifications, a few parts of their exam is multiple-choice questions.
So, you’re trying to equip them again, very much from first year at school, we are trying to get the young people used to multiple-choice questions, trying to get them confident in their approaches, and equipping them with the skills to go with their answering them, because I think, it’s such an important skill that they can be so creative about.
If they have a, b, c, d as their options, it’s not only important to identify the correct answer, but also be able to say why the other answers are incorrect, or (..) in doing that, I think that teaching the kids to be able to do that, I think that there’s as a creative approach to teaching in that sense. I think that you’re also equipping them with the skills to be creative in their approach to problems, because they are having to use their problem-solving skills and reasoning to decide what is the most appropriate answer here.
So, I would say that I used probably multiple-choice questions in that way.
Open-ended questions, though, I would say are probably the ones that I would go to follow if trying to encourage pupils to think in a creative way, because you’re not limiting their options.
You are not limiting their thoughts.
So, you’re really leaving it open to them, as the name of the questions suggest.
And I think that are giving them the freedom to go away and think about their answers, or to present their answers in whatever way they feel they want to.
It’s so important.
And I think that that’s probably the slightly more creative way of doing it, in my opinion, is the open-ended questions.
But I think that it’s one of these answers that I would say it’s too simple to say that one is better over the other.
I think that both are very powerful, when they are used in a well-planned way.

And I think that it does depend on the young people who are in front of you, and as a teacher I suppose you're the one who's best equipped to decide what approach you're going to use, and what type of question you think is going to really elicit their understanding more, I would say.

EDP: Did you have a good response from your students? Anyhow, also with distance

Jamie: Ahem, it's been challenging, I would say, but I think it's been not too bad, when I've been speaking to like colleagues from other schools, I think we're very similar to them across the board.
I think it seems there's limited engagement day to day, but I suppose they have (.), it's really difficult for them, isn't it?
When you're expecting them to do school working (..).
It's hard for me (.) It took me a while to actually accept that the kids aren't going to be sitting during nine to three every day and working on the schoolwork.
So, it's been not too bad.
I wish it was better, but everybody will say that.
But it's been not bad, though I'm really looking forward to going back to school.
It's just to see the young people, but more so just (.), not more so, but equally to get back and everything again, because it's been difficult working from home, especially for my girlfriend who's a teacher, as well.
So, she's been working at home, and she's a primary school teacher, but like we're trying to really sort of, not get on each other's nerves. [both laughing]
But yeah, it's been, it's been certainly very different, and I suppose, really interesting times, because we've developed so many online resources in a blended learning resource.
It means that actually stuff that would have taken us years to develop, that's not happened.

So, there's been so many positives trauma, and but equally and it's not the circumstances that you would want to be given the opportunity.

Joan, Physics teacher, 32 years of experience

Interview length: 50'28" Interviewed in August 2020

EDP: How long have you been teaching science? And do you have any teaching experience in different types of school? like selective additional support need

Joan: I've been teaching since 1989 properly. In 1988, I did my teaching practice and I did that in London in Deptford, so that was a high deprivation area, and then I've taught in two schools in Scotland, both like the school in the town.
No selective, no ASN.

EDP: What kind of work experience did you have before starting to teach? including any voluntary role, like previous jobs experience, if any.

Joan: Very little. Very little. So, but I've had stuff since.

EDP: Okay. The questionnaire is divided in three parts.
The first part of that was made up of these two questions. It's where we talk about your previous experience, then, there is a part concerning the Curriculum for Excellence, and the influence that it might have on your teaching style. And finally, there are the questions concerning creativity.
All of these in 11 questions, so (.)
[both laughing]

Joan: Brilliant.

EDP: So, let's start with the Curriculum for Excellence ones.
The first is: do you feel any pressure or constraint upon how you deal with the Curriculum for Excellence?

Joan: No, I was really excited when the Curriculum for Excellence came in, because I thought it was a chance to be local, be more adventurous, be more creative.
So, I really saw it as a positive, but I think we are still quite different.
We do things a bit differently.
I think we tend to be against the norm.
So, I think the idea of Curriculum for Excellence is really creative, you know, really exciting.
I thought it was a chance where you could just take your content and put it in exciting ways, you know.
Which is what we did in our school, but I don't think that's the normal.
I think people have generally just done it in the same way, and almost just not changed much at all.
And it's still very much the same.
'Here's a PowerPoint. Let's go through the PowerPoint'.
And I don't think that's what it was meant to be.

EDP: You experienced both: the time before the Curriculum for Excellence, the time after the Curriculum for Excellence, because it's now 10 years that it has been introduced.

Joan: Well, I still, I'm still trying to do things more excitedly.
And if pupils come into my classrooms, I would hope that they would see something different, exciting, problem solving, challenging.
I don't like to give them the answer.
I'd like them to try to come up with ideas.
If I've got, you know, if the HMI (Human-Machine Interface) come in, you know,

we try and do things differently.
So, I have tried to stick to that.
So, our course is quite different.
But I think it's, I think I've had to fight for it, and I've had to sell it, because when I was on my own, it wasn't so bad as the only Physics teacher.
But now there's other people, you've got to try and persuade them that is beneficial being creative, and getting the kids to think more, because I wanted to make it more thinking, and I wanted to put it more around a topic.
So that we do the topic and put the Physics in.
Almost what standard grade (.), I don't know if you know that much about standard grade. [Nodding no]
The standard grade Physics was like that, you know, it's called actually application lead.
Okay, so when we first got news of Curriculum for Excellence, I started putting up a heat topic for the region, where we took the idea of the house, though the heat house, and the pupils had to like insulated and do their own little experiments, and there was no right or wrong answer.
As the Curriculum for Excellence came out everybody in the region got given a doll's house, as well.
I sort of managed to get it, and I think there're probably only two schools that still use those.
And then, for our mechanics unit, we put it all around the topic of road safety.
So, we're doing all the speed-distance-time and things like that, and putting it in road safety, and we've won a European Award for that.
And I've been to the Parliament, but no Scottish parliamentarians see what we do, nobody's really taking it on.
They all say that's very good, but they won't, you know, it's still worksheets.
And so, you know, we're trying to teach it, because I think you can get just as much Physics in, and even harder Physics, by all building it around like road safety.

So, the Physics homework last week was actually about road signs, because my argument is going to be, 'not every kid is going to be a physicist, but every kid's going to be a road user'.

EDP: Yes.

Joan: So that's where I came from the Curriculum for Excellence, and I thought it had real potential, but it was never delivered on.
So, I'm quite, I feel like "the old one out", really (.)

EDP: And, do you think that the Curriculum for Excellence affected your teaching style, or the way you used to plan your lesson? and if so, in which way?
I mean we were already talking about that, but (.)

Joan: Well, I think it, I think it did it in the beginning,
Before the Curriculum for Excellence, I was still trying to do more problem solving, and we did some skills and thinking science (CASE), but I didn't do the topic around themes.
Then, I tried, I rewrote all the course, trying and doing it in this more creative way.
In the first year, it was fantastic and I was doing stuff that was really difficult.
I was teaching vectors to my first year and I thought,
'This is great!'.
But in the last four years, five years, I've really worried, because I think the students coming up haven't got, they've not got the basics.
I had a year where nobody in the class put their name on the front of their jotter in capital letters.
And, I'm feeling that the kids don't have the ability to think for themselves.
They've not, they've not got the ability to try and think for themselves, and try it out for themselves.
And in science you should be allowed to fail, isn't it?

You know, science is about trying it and if it doesn't work, nobody tells you off about that, because you found out in the finding, that you've got the wrong idea, but you still found something out.

EDP: Yes.

Joan: And that's a good lesson for life.
But the kids won't do that.
So, the kids won't try something if they might get it wrong.
Because they're terrified of getting it wrong.

EDP: So, problems with self-confidence. Is it a matter of self-confidence?

Joan: I think it's more than confidence, because I think they've been told, 'There's always this right answer'.
And therefore, they'd rather not try, than get the answer wrong, because somewhere along the line, they've been taught, getting it wrong is bad.
Instead of what we should be teaching is that getting it wrong is a life lesson.
You know, things will go wrong, and still go wrong all the way through life.
I'm trying to get them to see that, like when the first years come up, I try and say, *'Look, science is really about a life lesson'*.
I say, *'In science, you have an idea, you test it. And you know what? sometimes you're wrong and sometimes you're right. And it doesn't matter whether you're wrong or right, as long as you learn if it's wrong, and you go and change your idea'*.
I say, *'Isn't that good for life?'*.
But they have not got that message.
So, they're always looking for the right answer, and I don't think that that's what Curriculum for Excellence wanted to be.

EDP: Yes.

Joan: I think it wanted to be about getting the kids thinking and doing for themselves to exploring, and because then we will make students who are able to be creative, and go into jobs that are design and engineering, and thinking things like that.
So, I think I'm almost having to go back, and do far more basics (.) now, because they haven't come with any graphing skills.
They haven't come with any skills of being able to do things for themselves.
I found out last week that none of the kids in my class, in a second-year class, have ever made a paper airplane.
I mean surely everybody makes a paper airplane.
And they hadn't made a paper airplane, you know, and it's these little things that you assume that they've done.

EDP: Yes.

Joan: And they haven't done anymore.
I mean, I don't think it's just Curriculum for Excellence, because I think it came at a time when computers, and x-boxes, and play stations and things came in, and that's all their experience of playing.

EDP: They don't play outside, maybe.

Joan: They don't play outside.
I don't think they play outside.
I don't think they play with anything other than the computer and the games.
I mean, I think they have their wonderful worlds.
And I think Minecraft is very good.
One of the kids, yesterday or not yesterday, on Friday I think, was showing me (..).
We're doing space in third year, and they were showing me that little Minecraft space challenger that blew up.

EDP: Yes, also my daughter play with it from time to time.

Joan: They can be doing things like that, and, and that's great.
And I think that's helpful, but it's very much in there in a, what would you call it?
You know, in a virtual world. It's not in the real world, you know.

EDP: Absolutely not.

Joan: Not like I wouldn't like stuff like that, you know.
When they put all the bits together, it's all made up.
It isn't real world, it isn't design, technology, adapting, changing the science Process.

EDP: So, do you think that the current National assessments provide a good measure of the student learning, then?

Joan: Well, the ones I saw we had, I don't know if what they named was National assessments.
We did some like soft skills training and stuff like that, and I thought they were terrible, absolutely terrible.
One. The language was horrendous.
And so, you've got language that was like of about a 16-year-old, and you were testing people who were 12 - 13.
So, I didn't think that helped.
Also it's relying on you covering certain topics, and you can't cover everything, you know, for a content base course.
So therefore, if you happen to have done the topics that they have picked, you know, the kids are going to have done better, than if you've not done those topics.
So, I don't think they're testing the right things.

Well, I would rather have instead knowledge test, a more of a school-based test, you know,
if we were forced to do a national test.
I would like to see skills tested, problem solving, thinking skills analysing, rather than content, which can be accessed via the Internet (.)

EDP: Are the assessments you use according to the Curriculum for Excellence in the Broad General Education phase very different from the one you use to prepare the students for the National 4 or the National 5? and if yes, why?

Joan: I think we're trying to give them, introduce them to National 5 and National 4.
So, we're trying to start them thinking about like open-ended questions, that are in the exam.
So, I mean, I hate those questions in the exam, but I'm trying to introduce those.
But again, the kids are terrified of them, because they think there's a right answer that they're looking for.
What's that about? And they're not used to answering them.
So, we do need to train them and say,
'Look, there is no right or wrong answer, but don't waffle'.
Whether it's worth spending the time on that, I don't know, because I do question and valuing how well they can be marked, and I don't think it intentionally but I just think they can't be well marked.

EDP: Your school is in a deprived area, or is a mixed area?

Joan: It's a real mix. It's a real mix. It's very farming, very rural.
Nearly all our students come to school on the bus, the school bus, which I know doesn't say much, but you know we've got 14 buses, the sort of 650 kids, 750 kids, that come into school and a lot of them are in rural areas.

And I think there is some deprivation, but not a huge deprivation.
I can get you the figures, if you want later.
But I think what, what we've got, what we're deprived in is things to do, places to go.
We've got beautiful scenery, but you know the last bus home is at five o'clock, and that's it.
So, you know, some of the kids I have got, there is the school bus that brings them to school. So, they then can't stay for after school clubs, because they can't get home.

EDP: Yes. I got that.

Joan: So, that's, that's where our deprivation is more than the monetary, you know, but I mean it's the full range: you've got some very, very rich people, you've got some very poor people.

EDP: And, in terms of percentage, how many students decide to leave school when they are 16? More or less.

Joan: Most stay on, I would again, I'll get you the figures.
I'll see if I can get you the figures and I'll email them to you.

EDP: Yes, thank you. Do you think that moving from the general phase to the senior one can push to students to leave their studies earlier?

Joan: I think, I think, again, because it's a one-year course, and I can't ever see us going back to two-year courses and I think it's all for economics, because you can do a one-year course and you can have the fourth or fifth or sixth all in together.
What we used to find, when it was standard grade, was the boys quite messed about in third year, and the kids wouldn't take it seriously, but then, at the end of third year, they suddenly thought,

'Oh, maybe I need to do some work'.

And they'd like do the prelims, and then they'd have got the time to mature.

So, they can make their mistakes in the third year, and suddenly think, *'Oh, I'm not doing this very well'*, and grow up.

And now, because it's a one-year course, and it's all gallop, gallop, gallop, gallop, and there's so much to put in, in the content, the kids suddenly realize in January that, maybe, they've not been working as hard, and they can't catch up in that time.

You know, they'd have the second year to do it, and they haven't got that time anymore, and so I think then a lot of them give up.

A lot of them would then just go and sit a National 4 exam, and, of course, the National 4 exam isn't the same as the National 5 exam.

So, sometimes, you then wonder, and I'm not putting my hand up to that, how much they're being coached through the National 4, how much do they value it?

And I think a lot of the students just say,

'Well, I'm not going to bother. It's hard. I can't catch up. I have just dropped out'.

So, you know, there's a lot more, I think of pupils dropping out, whereas before you could say,

'Well, you just sit the general exam, and you don't have to sit the credit exam'.

So that they got something out of it.

So, I just feel that they're maybe not getting as much.

And then, they've only, they're only doing six subjects or five subjects, anyway, which I think it's sad, because then, if they want to take them further as well, if the students opted for the wrong ones, how, then, do they get back to science or other subjects?

You know, you can't pick up Higher sciences, when you drop them in second year.

So, I think it can be then that you're cutting students down so early, not allowing for them to change and develop, and (.) wanting more experiences.

Is that making sense?

EDP: Yeah, absolutely.

The Curriculum for Excellence states that students need to be considered in a more holistic way, that is in terms of their personal attributes, as well as taking into account their background. Do you think that the Curriculum for Excellence gives you enough freedom to do that, to consider them in a holistic way?

Joan: I think, I think it can just because again now, I think we're now beginning to focus on those senior phases.
But again, we live in a rural area, why shouldn't we make all our speed problems about tractors, and farming, and things like that.
So, that is more relevant.
But again, then are you limiting them, when they get to the exam phase by doing the stuff that they might enjoy? Are the things that they feel fits what they like?
That's not what they're going to get in their Nationals, and their Higher, and their Advanced Higher, which is going to be the standard.
This hasn't changed.
So that's really, that's a side of the curriculum that hasn't changed.
And they did want to build it from the BGE upwards, which I think they did, but they didn't link them.
The thing got this massive gap.
So, most pupils are now going back, I've got to start preparing them for it (ed. the senior phase) lower down in the school.
So, I think some of the BGE stuff has been pushed aside to just start teaching to the test for the exams, that you cannot avoid to think it's quite sad.

EDP: Let's talk about Creativity? Shall we? So, what does creative mean to you? which is your idea of creativity? and what do you think creativity means, or look like for your students? So, your point of view, and their point of view.

Joan: That's interesting.

Well, again, as I was saying to you when I emailed you, I always thought that you were either creative and you went into the arts, or you were scientific and went into science.

And I think that was an old belief, and it was probably quite into teaching, before I realized that science is very creative, and you have to be creative.

But first, my students, I think they think creative is drawing or drama.

I don't think they see that you can be creative, or need to be creative, as a scientist.

And I think also people in the arts and the drama think that, think that scientists aren't creative.

I think they think they're very logical and that's not true, because you totally got to be creative, to come up with your hypothesis and your ideas.

EDP: Obviously.

Joan: Again, I also think if you look at a lot of the people who have come up with those ideas (.), how many of them weren't successful at school because they didn't fit the pattern known? Einstein, the typical one, if he had done well at school, and he'd been moulded by education, would that creativity have been knocked out of him?

Because then would he have accepted,

'This is what's happened. This is why it happened'?.

And I think we've got to be careful in the way we teach science.

We still teach the students that they can be creative, and that they might be the ones that are coming up with something that hadn't been thought of before, and that there's still room for that, things like teaching them that dark matter and dark energy, you know, our big problems that are still to be solved.

Telling them, *'Look, it's not all sorted out'*, because I think most students think science is black and white.

And I think most teachers, whether they are in science or not, think it's all very black and white.

Instead of that, it's not like that at all.

EDP: I got it.
Can I send via chat a definition of a creative lesson? and then you can tell me what's your opinion about it.

Joan: Yeah.

EDP: Here it is.

Joan: [while reading the definition] Yeah. I like that. I think that's good.

EDP: Thank you. I wrote it, and it's the core of my thesis at the moment.
I'm asking to all the teachers I'm interviewing what they think about it, if there is any point that they don't agree, any critic they can move to, to improve it, you know, if they think that there is something more that need to be told.

Joan: I think that's what Curriculum for Excellence was meant to be.

EDP: I think the same.

Joan: And I think, and I'm not saying I've got it right, I think that's what I've tried to do, but I think that's not what's happening, because those exams aren't designed like that.
Their exams aren't interdisciplinary correlations.
So, they, you know, they were still in a little box.
In fact, what surprised, what I thought when the whole Curriculum for Excellence came out so naively was that all the, all the subjects would get round to the big table, the big circle, you know, Arthur's roundtable, and they would have all discussed what are the skills you need and when you need them.

And so, they got this pattern of, well, there's no good teaching.
And what I discovered is that the same subject, the different levels, never even spoke to each other.
So, the people who put together National 4 didn't speak to the physics people who put together National 5.
So, they didn't even speak together in the levels in one subject.
Let alone across subjects.
But I think if they had done that, if they started with the interdisciplinary and they talked around the table, I think it would have helped students.

EDP: Yeah. But the National 4, National 5, Higher, and so on, assessments are written down by teachers (..)

Joan: They are because I've written some.
They are very, they're very constraint.
So, the National 4 or 5, Higher, Advanced Higher, because I've written some papers, you know you have this.

EDP: Okay, so they're constrained by the curriculum itself?

Joan: Yes, and in science is very, very strict.
Very, very pointed, very directed.
And although it wasn't, because when I first wrote the exam paper for Advanced Higher, it was very much,
'The kid needs to know this. The kid needs to know this'.
And it was written out in those terms.
So, the questions had no flexibility in them, no.
So, you were very limited what you could ask.
Now they've tried to make them a little bit more wishy-washy, you know.
I have a knowledge about it, but under the surface that still means the same thing.

So, they still have to know very much,
'This is exactly what you need to put as an answer'.

EDP: And who is the people who evaluate the test once the students have done it? I mean, how they mark them?

Joan: Oh, they go back to teachers. So how the system works in Scotland (..)

EDP: Yes, in Scotland.

Joan: Okay, so what happens is that you have groups of teachers, who are on the examining team, and you have groups of teachers that write a paper, and then you have different people who check the paper.
They normally send it to people in universities to check, as well, that there's nothing bad in there.
And then it sort of goes through a six-month process, then it's typed top, sent out, and then a group of teachers again in the team, will discuss the paper and decide what is acceptable for an answer, and what isn't.
And then the markers will meet together, and the examining team will tell the markers,
'This is how you've to mark this question. You can accept this, this, this, but you can't accept that'.
So, it's all very prescriptive.
And then, the markers mark them, and then this examining team checks the markers.
So, we will sample some of the exam papers of the people marking, and if they're marking okay, so, they're allowed to be plus or minus two, so, if you mark and I check it and you're within two of what I think you get, you're a good marker, but, if you're not within plus or minus two, I will have to do some more sampling.
And then if we think a lot of yours are out, when they come to what's called standardization, they will call in.

It’s slightly different, because it’s now gone along, but they will check any student whose comes near to the cut offs, so between an A grade and a B grade.
So, they might remark on your papers.

EDP: Okay. The next question is: what personal traits do you associate with the students you teach who are creative? Can you describe the profile of a typical creative students?
Like if they are extroverted, or not, highly organized, or not.

Joan: That’s such a good question, and so hard to answer.
I think, for me, I would just like a student that doesn’t follow the crowd.
That’s prepared to stick the neck out, and say, ‘I think this, whether it’s right or wrong’.
But thinking it through, I would, in a way, put creativity down to thinking skills, rather than just accepting. Does that make sense?

EDP: Yeah. Which kind of personality would you observe in these people that behave like that?

Joan: I think (..), possibly they have more self-confidence.
I think generally they’re more extrovert, but then some extroverts can just be (.), they don’t think, they’ll just shout a lot, and (.), and then everybody will follow, and they’re not actually processing it so (..)
Oh, I’m trying to think of students (..).
I must say, I think (.), and again, I might totally be wrong, but I think it is possibly something that the more advantaged students are capable of doing.
Because I think some of the people who are in the deprived areas, I think they are having to spend so much of their time surviving and looking after children, looking at caring that actually, they’ve not got enough time to be well read, to be thinking about these other things, because they’re just trying to survive.

And I think then for those kids the importance of being creative isn't, it's not as high up their agenda, because they just, you know, why would you want to be creative?
I just want to survive.
So, I think it does, maybe I'm wrong, but I would suspect most of the people have done that.
You know, they've had books when they were little, if had maybe parents who encouraged them, and question them, and asked, you know, and said 'It's okay', so that they (.), that when a four-year-olds, or, you know, when you're two-year-old are permanently saying 'Why? Why?'.
Why do we knock that out of kids? Because that's what we want in a good creative scientist, isn't it?

EDP: Yes.

Joan: And yet they stopped saying that. Something must stop them saying it, and it is because adults just turn around and say, 'Oh, because it is all', or instead of saying, 'that's a good question'.

EDP: You know that thinking about this question, I used to answer to myself that the creative students were the ones that had that sparkle in the eye.

Joan: Yeah.

EDP: They had that sparkle in the eye and when you when you were talking, you could see they were already thinking about many things at the same time on what you were saying. That was creative to me, and that was when they came out with something.
Right or wrong, it didn't matter.

Joan: My, my first lesson, and normally I'd like it to be done in first year, but because of lockdown this year I suddenly realized the students hadn't got this lesson.
During my first lesson in first year, we do science with the students.
And then in second year they do Physics, Chemistry, Biology.
And I think a lot of students don't know what Physics is.
Saying to them, 'what's Physics?', most of them just, and I say, *'There is an IQ test in here'*, because I've also given them a title page to draw and it might be, you know, road safety, so, you did the least expect them to write that down.
And then, I say to them, I get two objects, and I say, *'Which of these will fall first?'*.
And the kids say, you know, the pen, or whatever, and then I drop it and I said, *'How many of you have done that experiment?'*, and they, *'No, no'*.
I said, *'Why not?'* and I said, *'Well, what is it?'*, and they said, *'That's all gravity'*.
I said *'But what is gravity?'*, you know, *'What is this thing?'*.
And they said, *'I don't know'*
And I tried to say to them, *'So, you said you know it's gravity, but you don't even know what that is, and never done this simple experiment of dropping two things'*, and then I pulled up the paper and I said, *'Now, which will fall first?'*.
'Oh, the pen, the pen, the pen'.
So, I screwed up the piece of paper.
And they said *'Oh, but that it's not fair'*, and said, *'Why isn't it fair?'*.
'Oh, but you screwed up the paper'.
'Okay, well, what's going to fall now? have you done that experiment?'.
And then, I say to them about, you know, *'do you feel you're moving?'* and then we talk about the Earth rotating in a year.
And it's just trying to get the kids, *'Wow!'*, that there's things out there for them to discover, and, like you say, the sparkle in their eye.
I do see that in kids, but it's kids that have almost been asleep for, for five years, that stopped asking questions.
And they've stopped, you know, they just want to copy from the board, you know.
Give me something to copy from the board!.

Why is anybody copying from the board in 2020?
And you, and you go around the classrooms, and they're copying from the board, and the kids want to do that.
And there's no place for that in science, you know.
We're in the 21st century, if you want a note put it on Teams, get it from the internet.
You don't need to be spending time taking that from the board, when there's the world for you to discover.
There's all these little simple experiments that don't even need anything, you know?

EDP: Yes.

Joan: You just go away and do those, you know, whatever little things they are.
You stick your pen in a ruler in a beaker of water, *'Why does it look like the pen split in two? what? why?'*
I asked those questions, just notice what's around you and then I see that sparkle in their eye, but it's almost as if they're clouded, because they've not been asked what they've thought (.).
Somehow, they've lost that and Curriculum for Excellence wasn't meant to do that.
Curriculum for Excellence was meant to make them, *'Wow. Look at this. Look, I can discover this! I can play with this!'*, you know.
And I, I feel really sad that, that I'm having to do that with the kids.
I mean, it makes them as hyper as anything, but I hope at the end of the lesson that they're going out thinking, maybe just appreciate, *'Wow, this thing I don't know, let's go and find out'*.

EDP: I talked to some teachers, who told me that usually the percentage of students choosing Biology and Chemistry is higher than the one choosing Physics, why? do you think is because it's too much connected to maths?

Joan: Again, Biology is seen as fluffy and cuddly, you know.

I mean, I always say, this is very bad, this is probably totally wrong for stereotypes (.), I can tell them, first year, *'If I play heavy metal, I'll play some good heavy metal'*, any of the kids will say, *'Oh well, I like that'*, well, you can do Physics.
Any kid that just wants to stick the makeup on you, you can go to that.
[both laughing]
And I know it's very bad, but it does seem to be that (..), *'Oh, it's too, (.) it's too hard I can't, I can't, I can't face that, don't, don't want to do that'*.
But, again, it's that because Biology is just about, you know, in our school that's all they're doing, copying from the board, and the kids love it, because they don't have to think, they're not thinking, they're just writing from the board.
You can get good results from that, because they've got all the perfect notes that they need to learn, but that's not going to make scientists out of them.
That's going to make students who can recall (.), you know, and set a test, but you're not going to get from those people the next pupil who's going to invent something creative in science as, you know, develop a vaccine for whatever, because all they will do is follow a procedure, and not stand out of the box and say, *'Well, what happens if we do something else?'*.

EDP: Yeah.
The Curriculum for Excellence asks you clearly to teach in a way that would enhance the creativity of your students, in which way do you meet this request? Do you think you have sufficient freedom or support to do it?

Joan: Okay. Well, I think one of the examples that we do is with the heat topic.

EDP: Mm hmm.

Joan: So, how I've laid out the heat topic (.), the outcome for the heat is (.), I can design a house that, oh gosh, I should know it, but it's anyway 3.0, no 9.

And, so we say to the students, *'Right, I want you to design an experiment, that you can test to see what you think can affect the heat loss from a house'*.

I say, *'Go away and design something'*, I said, *'I'm not going to (.), I'm not going to tell you whether you're right or wrong. The only thing I'm going to do is tell you if you're safe or not safe'*.

And so, some kids build houses out of Lego, and some of them haven't got a clue how to start, and some of them, and they're often the students who you wouldn't expect they sort of say, *'Can I try this? Can I try that?'*, and I say, *'Well, absolutely go'*.

What I would like to have done is having a bit more time to go through it, because it was very much all you have 12 lessons to do this, but some of the kids have come up with fantastic ideas, and they've done their own little experiments.

Keeping it a fair test is, is something that they need, and, you know, if they'd already learned that that would have helped, you know.

But some students, they just come and take a measurement.

They just take one reading.

I say, *'How have you proved anything?'*.

But again, what I'd like to have is longer for them as most of them do mess up the first time, and I don't want to stop them that first time, because I think that's where we're teaching them to be creative, to come up with ideas.

And again, I think in the last four or five years that's becoming harder to do, because they've not had that elsewhere.

And that's quite new and it shouldn't be new, because all the way through, you know, in P1, they should be playing with toys and finding out how toys are scientific.

EDP: My last question is: do you prefer to pose your students open-ended problems or multiple-choice questions? and which question do you think are more useful with respect to the development of creative thinking?

Joan: Okay. [laughing]

EDP: So, we talked about the open-ended questions in the assessments and now (.)?

Joan: If it was open-ended questions lower down the school, I like them to think, so more, 'Why does this happen?', you know.
But when it comes to them in the Nationals, I think that's harder, because, as I've said, there was a paper somewhere written that actually open-ended questions are often testing the knowledge of the marker.
[laughing]
Because if the marker doesn't know if that's right, sometimes, aren't they going to look it up?
Though I like creativity, but if it came to an exam, I think that maybe the open-ended questions would be something better for the lower school.
So, if we could put that in down into BGE (.), that might give them the confidence to say what you need to find out for yourself.
There isn't always the right answer.
Somebody has already done those experiments for us, and they have been tested but, you know, there's still other things that can be learned.
Now, and I love the quote, how was it (.)?
Lots of people have attributed it to different people, but I think it was meant to be like Lord Kelvin, that said, at the turn of the 20th century, *'There's nothing more to do, to discover in Physics, except more and more decimal places or better measurements'*, but, "nothing left to discover", did you know that?

EDP: No, I didn't know that.

Joan: It's a brilliant quote.
You look at what we've discovered about, they hadn't even found the electron by then.

Simone, Biology teacher, 6.5 years of experience

Interview length: 47'22" Interviewed in February 2021

EDP: The first question is how long have you been teaching science? and do you have teaching experience in different type of school? Like selective or additional support need.

Simone: Okay, so I qualified in 1999, so, I taught science for six and a half years over that period, so I've taught in a mainstream secondary, so, most of my experiences is in mainstream secondary.
I've also taught in a special school, a council run special school, secondary.
And I did primary science experience, as well.

EDP: What kind of work experience did you have before starting to teach? Including any voluntary role, or previous job experience.

Simone: Okay. So, for me, my actual route into science was when I left school in 1994,
I went straight to Edinburgh Uni to do nursing.
So, I had chosen actually to be a nurse.
So, I went up to Edinburgh.
And before then it had been, because I had A levels in Biology and Chemistry, and I was kind of thinking what to do.
It was kind of like, I wanted to do something science based, but I had a real urge to help.
And I was actually going to go into medicine, eventually, that was the route, that I think I was wanting to take, but then, while I was there, I realized that the pull of teaching was something, actually.
Because by the time I was in my second year, I thought 'No, I don't think nursing is going to be me', but I knew I was already thinking about nurse education.

So, I think actually, it was this teaching thing that was already so strong.
Then, I chose a course, that was for people in the UK, who had experience within a science field.
It was a kind of scholarship, not scholarship, but we got some money, bursary, funded to enter teach training.
It was a two-year course with teacher training attached.
So, I then went, that meant that I could apply for that course, do that course, and then over the two years, I wouldn't have been at Uni for any longer than I would have been.
I did two years at Edinburgh, had a gap here, and then did two years at Nottingham Trent and came out with my teacher qualification in '99.

EDP: Okay. Do you feel any pressure or constraint upon how you deal with the Curriculum for Excellence?

Simone: I suppose I don't. I'm quite unique in that way.
And the reason I don't feel a constraint is that I left high school teaching in 2002, and I then bought a drama business, taught drama after school run that quite successfully, sold that, and had four children.
And in that time that I was off, that was when Curriculum for Excellence was being discussed, as this new type of thing.
So, I have not been involved in it, in its kind of foundational stage, having to get my head around the fact that one minute I'd been teaching these credits, and generals, and standard grades, and now swapping into this new way of teaching.
So I was always on the periphery, as a parent, hearing that there was this new thing in Scotland called this Curriculum for Excellence, hearing about the kind of rationale behind it, but then kind of zoning out.
The bits that I heard sounded like, 'Oh my God, why am I out? I should be in because it just sounds like amazing', right?
Totally fantastic. Totally brilliant the stuff that I heard about.

But I wasn't involved in the nitty gritty, the changeover.
And then when I came back into teaching, three years ago,
I taught now in the way that I fundamentally believe is the right way to teach for me and the students.
So, I had spent all those years watching my own kids develop.
So, I don't feel the constraint of the Curriculum for Excellence, because I just don't view it as a constraining model.
The way I viewed it and reimagined it and articulated it doesn't constrain me at all.
I just don't feel any constraints.
The curriculum itself doesn't seem to be constraining.
I think the way it's articulated in each school seems to be the constraint, not the premise of the curriculum.

EDP: seems to be, or it is?

Simone: Ahem, I don't feel constrained by it, but I feel that the way each school articulates it, and the way the kind of groundwork that seems to have gone in is the constraining factor.
The vision of the people putting it together in each school is the constraining factor for me.

EDP: So now, more or less, it's ten years that the Curriculum for Excellence was introduced. Do you think that it influences or affects your teaching style, or the way you plan your lessons? and in which way?

Simone: I think it does. I think that, I suppose I've always looked as it is.
It's just a curriculum, right? It's just a set of ideas that are the bare bones, right?
They are, they have the bare bones, but they have an aspirational documentation that goes with it, as to where it sits, how it works into the landscape of the society, and how it fits.

I get all of that (..) and I take the view when I am planning my lessons, or designing my experiences for my young people.
I take the view, and I start with what I love, what I want for my young people, and then I build a curriculum around that.
And, inevitably, it always ticks off all the bits of Curriculum for Excellence anyway, right?
All of the bits that have to be covered, the benchmark, yes, right?
And that's where I, that's how I do it.
My kids are happy with that.
The department is really happy.
So, you know, there isn't a problem in that kind of way, you see?
And I don't have a problem with it.

EDP: And do you think that the current National assessments provide a good measure of the student's learning?

Simone: I think this is one of the issues I see is the Curriculum for Excellence, in the BGE, the broad general aspects of it.
This is a very expansive. It's very broad. It's very interesting (..).
You have this top-down pressure from, you know, even industry, university, FE colleges, Advanced Higher, Higher, 5, 4, 3 down that way.
That's how I see the kind of top-down pressure, right?
And there doesn't seem to be this happy medium, where the top-down pressure of what the employers are saying they want from the universities.
They're having to justify the type of courses they offer, because employers are saying, 'Well, your students are not employable', right?
So, the young people say, 'Well, what's the point of us going to university?'.
If enough say that, then the universities are going to be in trouble, right?
So, you then have this pressure underneath.

Well, the universities then put pressure on the schools to say, 'We need young people who can do this to get into the Uni', right?
And then, you can't get into Uni without having done Highers.
So, when you're in S3, your choices and how the curriculum is structured in school already are being dictated by what's needed for Higher, what's needed for National 5, what's needed for National 4.
You've got schools in Scotland starting their National 3 courses in S2.
So, effectively, that student's getting a Broad General Education up to the first year, up to 11, and then, after that, it's just a pipeline to further and Higher and that seems to be the problem.

EDP: do you think that there is also a marking problem in the National assessments?

Simone: In what way?

EDP: I was told by other teachers I interviewed, that they don't recognize the National assessments as a good measure of the student learning, as it's based on a three points mark, just 1, 2, 3. So, for example, a teacher said, you know, that maybe it would be more, how to say, fair, expanding the range of evaluation from 1 to 10 to consider all, you know, all the students' learning.

Simone: Yeah, because people can be in that spectrum nearer to two, but not quite a two,
but they still be a one, you know what I mean.
Yeah, so you have to have a bit more nuance in between the one and the two.
If these are distinct categories. Yeah.

EDP: Are the assessment that you use according to the Curriculum for Excellence in the Broad General Education phase, very different from the ones that you use to prepare the student for the National 4, National 5, Higher, Advanced Higher? And why?

Simone: Yes, they are, they are.
They are quite different, because I think they're assessing different maybe, different skills.
And it depends.
Some schools are gearing their BGE very much tied in with a type of language the young pupils are going to be expecting to come across at Nationals.
So, two years down the line.
When you're talking to students about certain aspects of curriculum, say (.) experimental design, you want to start using some of the language early on, so that they're quite used to it.
And that, I suppose, is the clearest crossover, the language being used for the kind of practical element of it, getting them involved in that is the thing, because that's the area that they struggle with the most.
Because learning the content is learning the content, you know.
Whether you're learning about forces in your first year, you're still kind of learning about the same. It might be more difficult, but it's still very content, knowledge, heavy (.) basis, right?
But practical skills are the bit that has the lowest marks across Scotland all the time, and it's always the most difficult bit that students struggle with, even when they come into S3, they still struggle with that.
So, I think that's the bit, that's probably the most (..) poorly taught, you know, probably both very poorly taught.
It doesn't do well with didactic kind of teaching very binary, 'Listen to me, do this. Listen to me do this'.
Which are the parts of science?
You can have them in the classrooms, you can talk, they can listen, they can write, right?

And they would learn about the body that way, that was one way you could teach that.
But in terms of breaking down an experiment, the kind of rationale, the kind of logical thinking, the kind of creative thinking that sits behind understanding, what the hell somebody was even doing when they put a scientific question together, that is very poorly taught.
Yet, the knowledge base that science sits on has come from that pipe of thought, you know what I mean?

EDP: Yes. You were talking about the pressure from the universities and colleges who ask to the teachers about what students should know.
I don't know anything about your school, such as if it's in a deprived the area or an affluent one, but do you think that in some way the transition from the Broad General Education phase to the Senior one pushes in some way the students to leave the school earlier? Maybe because they are not self-confident enough in approaching the new type of learning, the new type of assessments? Do you think that there might be this problem eventually, or not?

Simone: Ah, so do you mean in terms of like if a child was not doing particularly well, and they were in third year, they would leave in fourth year, you mean?

EDP: Yes, if you think that in some way they are influenced by this big change.

Simone: Yes, sometimes it is, but the thing is, schools are teaching that type of stuff much more early.
So, in third year, a lot of the schools aren't still may be doing a kind of a Broad General Education, even though they're supposed to be, you know?
They are supposed to be doing that still.
The children are entitled to the BGE right up until the end of third year.

Now, I know that in our school and the schools that my kids attend, that no National 4s,
and certainly National 5 has been done now.
My son's in third year.
And the course started off as something completely different, and then very, very quickly it slipped into life on Earth, which was the biology unit, but National 4 and National 5.
So, you know, you can flower up in all different language, but very, very quickly, in third year.
So, effectively, they do National 4 in third year, and they do National 5 in fifth year, right?
But, you're supposed to really be able to do a course, choose a course of interest in Nationals 3, right up, well right up until third year, and then you should be able to pick what you actually want to do.
So, it isn't a full-on science course.
They are choosing in second year.
They are choosing in third year.
And in fourth year they are choosing what they are doing in fifth year.

EDP: My daughter is in S2, and she chose the subjects already before Christmas.

Simone: Yes, that's right. Yeah, the S2 was around about this time, Christmas, January, they're choosing their third-year subjects.

EDP: Yeah, the third-year subjects, but the third year theoretically should be a Broad General Education one. So, they should do all the subjects, not the subjects they chose.

Simone: Yeah, they should be still doing the school, or just still have some time within there to do other subjects that the school would like to run.

Like, we have creative industries, we have other courses that they can pick up, you know.

EDP: The Curriculum for Excellence states that students need to be considered in a more holistic way. That is, in terms of their personal attributes, as well as taking account of their background. Do you think that the Curriculum for Excellence gives you enough freedom to do that? to consider them in a more holistic way?

Simone: I think so.

I think that a lot of the emphasis is on the holistic, but I think what happens though is that, at some point, coming into school, the first year, the curriculum of the schools hasn't been envisioned in a holistic way.

So, and that isn't bespoken enough to the students, so that they understand that they might be studying maths in this one subject room here, and then walking across the school to do science over here, but actually it's all part of a huge body of knowledge that belongs to the human.

And they're not seeing how these separate knowledge domains fit together in one bigger domain, which they are, you know, which is all part of how we are, and if you don't do it like that, what happens is, I think, that you have people then splitting off into maths type people, sciency type people, or the arty over there.

You're not seeing them able to then navigate which problem they can solve using different domains, or how the domains can come together.

There doesn't seem to be enough emphasis on how the domains come together, and this insistence that there is a literacy and numeracy and each health and well-being, which I get, doesn't then give equal status to these other bits.

But I think they're kind of thinking, 'Listen, if you've got somebody who's got pretty okay health and well-being, and they can read, and they can write, and they can do numbers, then you've kind of got the basis of what they need', you know?

But then, which I get, but I don't see the other subjects being really forced to come together or understand why they come together.

And also, I think we need to teach young people why there is this split, why there is this kind of splitting of the subjects, you know?

EDP: What does creativity mean to you? and which is your idea of creativity?

Simone: I think, for me, creativity is a kind of energy, I describe it as a type of energy, because I access it in different ways, like an energy.
I access it sometimes by something that I just have this sense of, this needs to take these disparate, disparate parts, and pull them together somehow, and make something, make something, that doesn't have to be something new.
It doesn't have to have this kind of new innovative, that's something different, that's innovation in its way.
But creativity to me is about taking these different elements, these different parts, this different things, different ideas, and it's the act of bringing them together, assimilating them into some kind of sense, some kind of order in your brain, or your body, and then putting them back out there.
So, that's how I kind of see it.
So, if I use that as my kind of model, it can help me explain creativity in any of the domains, because it is just this raw thing that is there, something that we do, and sometimes it's unconscious, sometimes it's conscious, but actually, I think essential to living.
It's an essential, everybody does.
Rich, poor, whatever, you kind of do it.
You cannot live without doing it, but some people have learned a mechanism by which they can harness it.

EDP: What do you think creativity means or look like to your students, instead?

Simone: I think, when I talk about creativity, and I have, you know, done science courses with a strong focus on this.

When we first talk about it, they think it's very much about the arty type activities, okay?
They're thinking it's very much based in the art area.
But as I've just explained it there, it doesn't have a domain, it sits through any of them.
It's just a thing that exists in a way.
So, I try and teach them about the fact that there isn't a domain that it fits in, and what I do is showing them how this fundamental idea of taking things all over the place, assimilating them, and exploring can be used in any domain, right?
So, I show them, and I explain about history.
Like I've been collecting articles, where it's shown in different areas.
Like I might be reading a history article, and someone mentions the word creativity, and I'll quickly save that, so I'm hoping to kind of have a display about them.
This week, when I was watching my nephew playing rugby in the weekend for Scotland, what was really interesting about that was one of the things that was mentioned about him, you know, and I've got an article from a couple of years back, talking about creativity within the rugby what it would mean, right?
So, I use this to show that this word creativity has a fundamental meaning, and each domain takes it, and you teach the people engaging in that domain, that this skill that you're doing now, is called creativity. In rugby.
A chef could take it, you know, and show it, but a chef who's creative might not necessarily be a great rugby player, because there's actually a huge knowledge and skill base for that domain, that allows the creativity to be expressed.
You know what I mean, so that's how I kind of teach it.

EDP: Can I propose you a definition of creative lesson via chat? And then you can give me your opinion about it? Here it is.

Simone: Okay, so, let's see close, I wouldn't say that's great.
That wouldn't come into my definition of creativity.

EDP: While you were talking, it reminded me a lot about this, such as using topics that are meaningful to students.
This thing that you were saying about taking things from here and there, made me think about that.

Simone: Yeah. Right, okay, so 'a lesson is creative, if the teacher is able to engage the students in developing their understanding of the subject under study in a new way', right?
So, if you just left it like that, would that make the lesson creative?
No, it wouldn't, right? Because if you just take it on that bit there, right?
Because what you've done is, you've just taken a new way of showing the children, developing their understanding of the subject, in a new way.
So, if you don't normally use PowerPoint, and this time you use a TED talk, that would not be creative.
Okay, unless you had previously realized that your PowerPoints were not working, your PowerPoints were no longer meeting the needs of the students for which you had originally designed them for, and you looked and had reflected on the feedback that your students have given you, and you thought, 'Right, so I designed this experience, which was my creative input based on what I thought I needed to do for students. Now, it didn't work'.
You've listened to the feedback, and you thought, *'Right, okay, what would now engage them? I know, I'll try'*. So, you're experimenting with this thing called a TED talk.
I'll try that. I'll try that. I'll have a look. I'll see.
That makes it innovative and creative, if you are looking at, say, student engagement, okay, in that type of thing.
So, to me, the creative aspect has got to be that the teacher has designed some kind of experience, based on the need, right?
You have created something, a learning experience, the learning experience has been received the feedback from that, then informs the next part of the teachers offering,

but all the time, the experiences of the young people are driving her or his creative endeavours, and within that sphere, you have these young people who have their own creative energies that you can tap into.
If you then take that Ted Talk, or if you then take the PowerPoint, and then get them to design their own PowerPoints, justify their revisions, talk about why they've chosen that stuff, that in itself is a creative act, because it sits within your larger expression of your creativity, but just take it a new way to show young people something.
You've got to tap into this idea that there is this kind of design of an experience, which means you've got to take your knowledge of the curriculum, your knowledge of young people, your rights respecting curriculum, your inclusive curriculum, your anti-racist education curriculum, and design an experience for those young people.
And that's your creative output, is the design of those experiences for young people, based on all of these other disparate parts that you bring together, and offer out to the young people.
But it's always about that you've designed.
You've got to design and the creative energy is about the design, the design, the design.

EDP: What personal traits do you associate with the students you teach who are creative? If you can describe a profile of a typical creative student?

Simone: The students that I've got who are particularly creative are, I think they're curious, right? Because, yeah, the curiosity is driving their need to branch out, find out, look out and understand the world.
And the more they are doing that, whether it's reading, writing their own materials, search, you know, that actually broadens their knowledge base.
So that when they come to assimilate things within themselves, you might have some of them who have understood something (.) from the dance world, for example, movement in a dance sense, and they're able to bring some knowledge of that

movement to explain something about the movement of particles, for example, or articulate something about the movement of particles.
And they're starting to assimilate ideas in their head.
So, curiosity has to be the driver, because curiosity fills this reservoir of this pool of ideas,
that you can then pull from when you need, right? And one idea begets another idea.
So being curious.
They're really keen to try out ideas, which again, is part of their curiosity.
I think curiosity drives them, because they want to understand, they want to figure out, they want to make sense.
They're happy to talk about what they don't know, they are happy to talk about what they don't understand, and they see that the world is just this place that they can just go and find answers as much.
So, that's what I find with a creative student.
I don't think necessarily they have to be introverted or extroverted or anything like that,
because they're quite happy to sit and figure out.
I think it's this wanting to figure out aspects that drives the creative, and then this desire to share it, this desire to share what they have tried to figure out, you know?
I think that these are the two traits that I would say.

EDP: Many teachers mentioned self-confidence like a main trait.

Simone: Okay

EDP: what do you think about it?

Simone: I don't know if necessarily they have confidence in themselves, because sometimes, you know, the more you can find out, it can be very scary how much is

left still to find out, how much more is unfound out yet, and that can be quite, you know, daunting, so that you can kind of bring people into themselves a wee bit more. I don't know, I know lots of students who are particularly creative, but aren't necessarily self-confident, because I think that way we always think it's going to be this break kind of expressively big showy way, but a quiet student who's sitting there trying to figure out some puzzle of the universe, or something, doesn't necessarily have to have a lot of self-confidence, you know.
So, it's not something that I particularly associate with being creative

EDP: Your answer made me think about what another teacher said.
We were talking about the pandemic, and she was the only one that made me look at the pandemic in a more positive way.
It's a challenging time, but it also offers some positive things with respect to teaching and respect to the students.
For example, the fact that during the pandemic it was easier to the shyest students, as they were in a different context with respect to the class, to come out with questions.
They were not covered by, let's say, stronger personalities, and so some teachers found out that these shyest students, that were like disappearing in the class, instead, they work more and they were more proactive
This teacher made me consider the pandemic from the point of view of the fact that the assessments were cancelled and so, in so she was saying, 'I think that was the pandemic that gave me the possibility of considering them in a more holistic way, because I had the time, and I had no stress about having to prepare these assessments'.
Do you agree in some way?

Simone: I think that's true.
I think that, I mean, I'm not teaching science right now in the school.
I have a different role in the school.

I was teaching last year during the last lockdown, but I know that for the students that I know, that they're not having to do the exams, and trying to show what they learn in a different way is quite interesting, you know.
They're quite looking forward to that, some of them are quite looking forward to that, you know.

EDP: The Curriculum for Excellence asks you clearly to teach in a way that would enhance the creativity of your students. In which way do you meet this request? and do you think that you have sufficient freedom or support to do it?

Simone: Yeah, I think that (.) one of the things I do well, quite well.
I always come from what I'm interested in and what they're interested in.
That is the premise, because everything, if you look at the way that my subject, it's structured, everything on the news that is biology can fit into one of those.
So, it's not difficult to back reference, you know?
Say 'oh yeah, I'm taking off this, I'm taking off this".
So, I've got a list of articles, that I've sent my son in WhatsApp over the last couple of months, and if you go over them, these things like, 'Oh, will this come back into Scotland? or the Eurasian lynx? or this bird is the only bird that makes tools?'.
Just interesting articles in biology, and every single article will somehow link back to the Curriculum for Excellence.
So why not just start with this type of things.
I have this absolute vision of, of being able to (..), because I do teach that.
I find a newspaper article, and we print all off, and we go through it in class.
Or I find a documentary, an odd documentary that I like.
Or I see a news script on something and then, what I do is, I then go through, the kids then go through every single sentence, and we get a gist of what's actually being said, understand, and then we go and find the knowledge that helps us understand what this article is actually about, you know?
Why is the scientist, you know, talking about depleting numbers?

How would he know depleting numbers?
What does depleting numbers of this animal actually mean?
Why is this even significant?
And we do it that way, we start with what they are interested in, what is happening currently, and then we build up that way.
And I then give them different jumping off points.
So, if they want to show it to me in a poster, or this type of thing, I will have showed them how to set the poster out in a way.
I didn't tell them exactly how to set up with the criteria and the content, so that even if it's a different medium of expression, it's not like a big written assignment, the content that I will mark is still there.
So, the marks will always be the same for every student.
The criteria for the contents will be the same, but the way that express that can be different.
So, I don't care if it's a podcast.
I don't care if it's a poster.
I don't care if it was a big piece of formal writing or prose, as long as the scientific content, which is what I'm assessing, is there.
So, I allow their energy of who they are, to come through, and I think what's really important with creativity is that you keep letting them understand that that's what they would be doing in other jobs in normal life.
It's no different to what the artist does when goes off to research, or a designer, you know?
So, showing them how to research, showing them how to take their own idea, and turn it into something testable.
And that doesn't matter what domain you're in.
You observe the natural world.
So, the curiosity, the observing in the natural world, or in the world can then be articulated into something testable, and the results of that can be articulated in

different ways, whether it's a research paper, whether that's a latest perfume, whether it's a new brand shop on the high street, the same process has to be carried out.
And it just sits in these different domains.
So, it's very much about critical literacy as well, showing them how to read something critically.
The other way around is the more they engage in their own narrative, the more easier is for them to see how other people are shaping narratives for themselves, that they want to use to influence you.

EDP: Do you prefer to pose your students open-ended problems, or multiple-choice questions? And which questions do you think are more useful with respect to the development of creative thinking?

Simone: I think that they're both as important as each other.
So, I don't oppose them.
I don't have the binary definition, okay?
So, I will have open-ended questions, because at some points in a project, you need the open-ended question, okay?
And that is the kind of divergent creative thinking you need.
Then, at some point, you will have to focus it on one of those areas or two of those areas, which is the convergent creative thinking, because you can't keep expanding, expanding, expanding forever.
It'll freak out your brain and you won't get anywhere.
Then, when you don't, when you've converged, you then can go through this cycle, again, of new open-ended questions, but they are new, like a fractal branch, you know?
They are hugely open-ended questions, but they've been the result now of a little finding the focus, then you do that again.
So, they both need to be there, and I don't oppose one or the other.

But in a question if I was given an exam question, you know, if that's how you're meaning, then yes, I wouldn't have necessarily like an open-ended question, I'd have a long answer session where you're still looking for these specific points of, of knowledge.
Then, yes, they can understand this, this, and this, but the question about the open-ended or the multiple-choice can be one for how you design your curriculum.
If you have to summon your S1, S2, S3 curriculum, would it be open-ended, or would it be multiple-choice?
I mean, I would say that I would favour the most the open-ended curriculum with elements of multiple choice within it.
That's what I mean.

EDP: You know when we talked about the problem of the evaluation of the assessments?
I was told by several teachers that they have to teach the students how to answer to the questions, because in the National assessments, in the open-ended question, clearly, a short answer might have the same kind of mark of a longer one. But, don't you think that when you teach them how to answer, you are in some way, putting in some limits to their creativity?

Simone: I think that, I think there's two issues, okay?
The two issues seem to be how we teach young people to be scientific, regardless of if they're going down the Higher biology or a further education route in a science, okay?
That's one because there has to be a pipeline for that, but there has also to be a pipeline for students to come out broadly scientifically minded functioning in society, okay?
And those two, sometimes have a clash, because there does need to be this drilling down of the knowledge base that science has.

So, that you can go on to do medicine, and all of the kinds of pipelines to Higher education in various science route, but being able to look at something scientifically, being able to understand, to try things out, to test them, that type of thing (.), but part of the limit is that if you don't teach young people how to, at some point, within their science course, answer the questions that will test their knowledge of the science, that they have been taught in that way, so, they can go on and do these exams, you actually are failing them.
And it doesn't matter how scientific you are,
how creative you are,
how beautiful your creative curriculum is, right?
If you don't spend time doing that, then you let them down,
because that is the system by which they're going to be judged,
and they don't know the system because they've never been in it, right?
They don't know this kind of, they ask you in this kind of weird way,
and you've got to try and figure out what it is they're trying to ask you,
you have to bring them into that knowledge base.
And that is your role as well as a teacher,
but that doesn't have to come at the expense of your creativity, their creativity,
and who they are as people.

EDP: I have just one last question.
I promise it's the last one.
Do you think that when you teach with the creativity,
you are enhancing the creative skill of your students?
That means, when you teach with creativity, do you teach for creativity?

Simone: I think I do.
I think that well, I know I do.
That is my that's the thing I do.
I think that I have made a really conscious effort.

I think it has been a conscious effort,
but it seems unconscious to me,
because I suppose it's how I am (.),
to tie their creative output with my happiness as a teacher.
So, I have put the two together.
And without one of them,
I don't feel happy if my students aren't actively engaged in creative tasks,
even with a science task, which has a high academic emphasis.
And I still (..) teach it in a creative way,
and expect them to be creative in how they do it.
I set it up so you couldn't,
if you're not creative, you can't do it.
But it does, it answers in such a way that they can learn to be creative as they do it.
I know where I want to get to.
I know what I want them to do.
And I just make, have this way of making them make these connections,
and I, and it's actually,
it's actually a very logical way to work.
But it's like I've taken the creative aspect and broken it down into these kind of really logical steps,
that anybody can do,
anybody can learn, you just have to value it, you know?
And that's how I do it.
So, if they're not doing those types of tasks,
or if I haven't found a way to put that type of task into the lesson,
I don't feel I'm hitting the mark as a teacher.
And that's very important to me.
So, that's how I kind of teach it, I suppose.

Appendix L

Laila – Chemistry Teacher

1. Year/Class First year

2. Lesson Title Reproduction in Plants
3. Curricular Areas to be Addressed

I have explored the structure and function of organs and organ systems can relate this to the basic biological process required to sustain life. (SCN – 3-12a).

When I engage with others, I can make a relevant contribution, encourage others to contribute and acknowledge that they have the right to hold a different opinion. I can respond in ways appropriate to my role and use contributions to reflect on, clarify or adapt thinking. (LIT 3-02a).

I can show my understanding of what I listen to or watch by commenting, with evidence, on the content and form of short and extended texts. (LIT 3-07a).

4. Links with Pupils' Previous Learning/Knowledge/Experience

Pupils will use their knowledge of plant organs and flower structure to enhance their understanding of reproduction in plants.

5. Aims of this Series of Lessons

Pupils are learning about cells, organs and reproduction in plants and animals. They will be able to compare the difference of animal and plant cells.

6. Learning Objectives for this lesson: (which you may share with pupils)
(Reminder: there should be evidence in your lesson plan that you, perhaps in conjunction with pupils, have devised brief success criteria which will help them with the lesson's activities. In this way they will be more likely to achieve the Learning Objectives).

By the end of today's I will be able to:

- State how pollen is transferred.
- Identify male/female sex organs.
- Describe the key stages of fertilisation in plants.
- Make relevant contributions to my group.

7. Findingoutwhatpupilshavelearned.

• What strategies will you use to find this out?

Going round each group to see their reasoning behind the answers that they got. Get each group to present back to the class to see if they understood the stages of fertilisation.

• What strategies will you teach pupils to help them find out?

Group discussion and to logically come up with an answer and to have reasons behind it. Have each group report back after their storyboards are completed to explain their groups reasoning to their storyboard.

8. Differentiation

One boy in the class is severely dyslexic. Processing is good but slow at writing. Any long passages to copy will be printed out for him. He will be put in a group which will have a mix of picture and (b) written resources. His role in the group will be predominately discussion and reporting back than writing the storyboard.

A boy in the class has Meares-Irlen syndrome. I will not have many PowerPoint slides and mostly resources in front of him.

I have created an (a) and (b) text for the resource packs. The (a) text is slightly more detailed and the (b) has the basic important only.
The groups will have a picture and either an (a) or (b) text for each stage.

9. Resources: (please state to what extent these resources have been developed completely by yourself, whether they have been partially or totally developed by the department or whether they are commercial or web based resources.)

PowerPoint developed by myself.
Storyboard resources adapted from BBC Bitesize. Short video clip from YouTube.

10. Other factors to be considered: e.g. background to class, including organisation / risk assessment / safety.

The groups are organised to take into account all abilities. Each group will have a mix of pupils and pupils who tend to carry on will be in groups which will encourage them to work.

11. Outlineoflesson/teachingstrategies/timing

1.05pm-1.12pm Get pupils in to their groups. I will have the group list on the board and take the register. Introduce Dr Brand to the class. Starter questions on

1.12pm-1.14pm 1.14pm-1.21pm

the board. Reminding the pupils of the male and female structure of a flower.
I will run through the learning intentions with the class to convey the structure of the lesson.

I will show a short (1 minute) video explaining the stages of fertilisation in plants.
I will explain to the pupils what will happen today. I want the class to create a storyboard of reproduction in plants.

Each group will have to create 4 key stages of fertilisation. The groups will have a resource pack of a picture and either (a) or (b) text for each stage.
I will tell the class that, in total, they have 8 pieces of information. They need to link the text and picture together and then put their matched picture/text in order of the stages of fertilisation.

I will mention to the class they have a labelled diagram in their jotter of the parts of the flower to refer too.
I will explain to the class I would like additional ideas on the storyboard too. (e.g. what is important about the flower? Why is the flower attractive to bees or insects?)
I will have on the PowerPoint slide an instruction list to keep the groups on track.
I will assign each person in their groups a role during the process – time keeper, spokesperson and leader.
The groups have been set up to ensure a mix of abilities in each. Pupils, such as HM, will be assigned the time keeping role so he does not have to do too much writing.
I will walk around each group to see their progress. Making sure everyone in the group is working and not ignoring their roles. If groups ask me any questions that could potentially give them the right answer to the storyboard I will make sure I rephrase my answer so that the groups can still work it out themselves.
I will encourage EM, RC and JF to participate in their groups as they have a tendency to sit and distract the group or not participate.
I will have extra (a) and (b) text to give to the groups as an extension to see if they can match the extra text with their stages.
I will get each groups spokesperson to come up to the class and briefly explain their steps and why they decided on the order.
I will write each groups sets on the whiteboard and together, with all the groups, we can come up with our own storyboard about the stages of reproduction in plants.
I will run through the order of the stages of reproduction on the PowerPoint to sum up what the groups should have had on their storyboards. Or reiterate what the class has come up with already.
I will run through the learning intentions with the class again to demonstrate that they were or were not success with each of them. I will remind the class that they have homework due next week. Each group will pack up their resources and bring their posters to the side of the room.
The class will stand behind their chairs until the bell rings and I dismiss them.

1.21pm-1.36pm

1.36pm-1.46pm

1.46pm-1.51pm 1.51pm-1.55pm

Additional resources – crossword on plants. Summing up from the other lessons on plants.
12. Next Steps: homework / follow up / future lessons:

Next lesson the class will be doing a comparison of animal and plant cells and reproduction. They will be reinforcing their learning by being able to spot the difference between the animal and plant cells.
The class has on-going homework for the lessons to follow up what they have learnt in the class.

13. Post lesson analysis / evaluation

Class: 3G2 **Level:** Nat 5 **Lesson Title:** Intro to Acids and Alkalis **Learning Objectives for this Lesson**

Pupils will be able to state that acids have a pH <7, alkalis have a pH >7 and neutral solution haveapHof7.

Learning Intentions for this Lesson

Find out what pH acids, alkalis and neutral solutions have.

Success Criteria

By the end of today's lesson I will be able to:

- State what pH acids are
- State what pH alkalis are
- State what pH neutral solutions are

Resources

PowerPoint made by myself Acids/Alkalis from department Orange juice/soap solution by myself

Sequence of Activities

Have pupils come in and get their jotters out. I will give everyone their test results back. I will give the class a few minutes to have a quick look over them. Take register.

Approximate Timings

2.50 – 2.55

I will go over a few of the questions. Explaining more towards the last two calculation heavy questions. I will write the last two questions on the board for the class to see how they would tackle them. I will take the answer papers from the class and ask them to take a new page in their jotter and write "Acids and Alkalis" as a heading.

2.55 – 3.05

3.05 – 3.10

3.10 – 3.15 3.15 – 3.17

3.17 – 3.20

3.20 – 3.30

3.30 – 3.40

I will explain that acids and alkalis are common in the lab and at home. Usually we see corrosive labels on the acids and alkalis and they aren't always that dangerous – our household acids/alkalis aren't dangerous. I will ask the class to think of as many household acids/alkalis that they can think of. I will write some on the board and go through my examples.

I will explain that we have common lab acids and alkalis that we use regularly. I will introduce the pH scale to the class. Getting answers from each on what they already know about it.

I will ask the class how can we measure the pH of a solution? Have the three examples on the board and say we are going to use two of them today.

I will explain that we will test the pH of 4 different substances. We will use universal indicator for the first two and pH paper for the last. I will ask the class why we should use pH paper for orange juice?

I will get the class to copy down the table. Collect a test tube rack, four test tubes, droppers and the solutions.
Pupils will put 3cm depth of solution in the test tube and test the pH. Tweezers will be used to check the pH of the soap and orange juice with the pH paper.

I will get the class to tidy up and tell me their findings. I will fill in the table on the board and get each group to explain what they got.
I will have the revision questions on the board and get the class to copy and complete.

Evaluation

Carter – Physics teacher

Lesson 8
The Human Chromosome Complement and DNA

SAoL

Knowledge and understanding of scientific ideas, principles and concepts related to Biological systems

SAoL detail & Related Es & Os

Learning Intentions

Success Criteria

1. I can describe the composition of

   DNA, stating the double helix shape which joins by four bases.

2. I can explain the human

   chromosome complement and state how the sex of a child is determined.

Task / Evidence

DNA; extraction and function; Benefits and risks of DNA profiling

By exploring the characteristics offspring inherit when living things reproduce, I can distinguish between inherited and non-

inherited characteristics. SCN 2-14b

Note Research Report Video

Construct a model of DNA

LI: To explain the composition and function of DNA.

Resources Required

Human Chromosome complement worksheet DNA construction card

Health & Safety Considerations

Suggested Teacher Plan

1. Recap on structure of an animal and plant cell. Get pupils to draw and label an animal and plant cell on a sticky note or in their jotter. Enforce the point that it is in the nucleus we find DNA.
2. Go through the PowerPoint slides. Slide 5 explains how different organisms have a different number of chromosomes and that makes every species unique. Pupils are to copy the note on slide 6 explaining the role of a chromosome.
3. Pupils are to choose an Inherited Disease to research (this can be completed as a homework task or in class).
4. Pupils are to complete worksheet on Human Chromosome complement. Explain how humans have 46 chromosomes in total, 23 from mum and 23 from dad. They are to be able to explain that males are XY and females are XX.
5. Go through the slides explaining the composition of DNA. It is trying to get the idea across that DNA is what determines who we are. Glow also has a video to watch if pupils are finding difficulty with the concept of DNA.

6. Pupils are to collect a DNA template sheet. They are to colour the bases in the correct colour, best to go with the colours of the PowerPoint. They then have to cut out the diagram. Diagram 1 need to be cut individually so it can be glued on to diagram 2 (the strands). The strands tell you exactly what number should go where. When pupils are finished you should get a double helix shape.
7. Pupils are to copy note from the board. Filling in the blanks.

Other Related Textbook Work and Worksheets

Exploring Science 9 – p10 & 11, 12 & 13

Homework

Forces & Space Lesson 3 – Drag & Streamlining

Brief Overview		
In a further investigation into friction pupils aim to understand how the shape of an object can be adjusted to achieve a more STREAMLINED shape. This involves a class experiment with a limited design and competitive element using play dough to compare how the same mass of object will fall through water at different speeds when its shape is changed.		
E&O	**Learning Intentions**	**Success Criteria**
By contributing to investigations of energy loss due to **friction**, I can suggest ways of **improving the efficiency of moving systems**. SCN 3-07a	We are learning about how shape affects air friction.	I can take part in a fair experiment to compare the drag forces on two or more shapes I can suggest ways of reducing friction on objects moving through air or water by changing their shape.

Equipment & Resources Required

Paper Resources Equipment Trays Order from Technician

Experiment write-up booklets	Large measuring cylinder Electronic Balances (x4) Play dough Stopclocks/Stopwatches (±0.1s required)

Health & Safety Considerations
Ensure pupils do not eat dough. Dough is sticky when wet. Coloured dye in dough can stain clothing and skin(not permanent) Take care with large (breakable) measuring cylinder. Use a large jug to fill it with water and take great care when emptying.

Lesson 3 Suggested Plan

Lesson Introduction (5 mins)
The green shape will create the least air friction, next best being the circle, then the orange triangle, then the yellow pentagon. Try to help children to understand that for air friction the shape both at the front and back of the object must allow air to flow over smoothly. Just in case anyone asks, it is entirely different in supersonic airflow!

Task 1 (10 mins)
Copy and complete exercise using words from the word bank at the bottom

Task 2 (30 mins)
Depending on your class you may wish to introduce a competitive element to this task with respect to the final “pupil designed shape”. You can design one per pupil or one per group. Give pupils just 3 minutes to design their shapes once they have written out the aim, method and results table. Gather class around measuring cylinder with three or more timers. Test the cube, sphere and cylinder as a class then allow each pupil / group to test their own shape. Only drop each shape once, but use three or more timers to measure the repeats. This saves having to empty and fill the cylinder many times. To emphasise the point that they are all the same mass, you could measure each shape before it is released, and release them all from a position where they are just touching the middle of the surface of the water in the cylinder. Important to keep the experiment fair. If pupils have time they can draw a bar graph of the results of this experiment. Note that the shape with the LEAST time experienced the LEAST drag and so can be said to be the MOST STREAMLINED.

Other Related Textbook Work and Worksheets
Textbook Work Exploring Science 7: 7Kb – Friction **Worksheets** Exploring Science 8Ja(3) - Word search

Forces & Space Lesson 10 – Looking Beyond

Brief Overview
All we know from outside our solar system is from looking through telescopes. This lesson gives an introduction to stars, concentrating on mains sequence stars like our sun. This topic is broad and very complex so it is not recommended to get too deep into the science of this field at this stage of education. Concentrate on what will be required for the next lesson, a knowledge that stars can be very different, and an understanding that some stars have habitable zones, and might even have planets in this zone, but even then they might not actually be habitable.

E&O	**Learning Intentions**	**Success Criteria**
By using my **knowledge of our solar system and the basic needs of living things, I can produce a reasoned argument on the likelihood of life existing elsewhere in the universe.** SCN 3-06a	We are learning how to use our knowledge and skills to evaluate stars.	I know that only some stars have planets I know that not all of these stars will have planets in the habitable zone.
I can solve problems by carrying out calculations with a wide range of fractions, decimal fractions and **percentages**, using my answers to **make comparisons** and informed choices for real-life situations. MNU 3-07a	We are learning to work with percentages.	I can work with basic percentages without the aid of a calculator.

Equipment & Resources Required

Paper Resources Equipment Trays Order from Technician

class set: "Percentages in astronomy" sheets

Health & Safety Considerations

none

Lesson 10 Suggested Plan

Lesson Introduction (5 mins)
Blue is simply incorrect. Using a telescope, this is how we can see asteroids, but they are far too dim to be seen without a very powerful telescope. Orange is pretty much spot on. We see a mixture of stars and galaxies when we look up, as well as planets. Green is true of most of what we see, but some are galaxies, and a few are planets. Actually, we can see satellites, but not from their lights. It is possible to see reflections of sunlight reflecting of satellites in low earth orbit. Sightings are most common either just before sunrise or just after sunset, but can be seen later in the night as well.

Task 1 (10 mins)

Copy and complete exercise using words from the word bank at the bottom

Task 2 (15 mins)

Watch and discuss the Keplar video. Discuss what is meant by a habitable zone for a star.

Task 3 (20 mins)

Run through the example percentage calculation in the PPT, and if your class are struggling, make up another one to run through with them. They should know how to do this from maths.

Hand out and explain the worksheet “Percentages in astronomy”

The sheet should be self explanatory, but it would be wise to talk them through exactly what you expect. It may be worth setting this as homework if it is not finished in class. You can choose to do the graph or skip this depending on time. You may also wish to make a bigger deal of it and do it on graph paper.

If you have time you can introduce the topic of exoplanets and discuss what sort of planet (bearing in mind all we have studied in this topic so far) we would be looking for if it were to have a chance of supporting life (bacterial or complex)

Other Related Textbook Work and Worksheets

Joan, Physics teacher

Contents

Prior to the course

Please introduce students to what Physics is. Chemistry and Biology are easier to describe to students than Physics and it is amazing how many still don't have a good concept of what Physics is long after sitting in a Physics class.

What is Physics?

Physics is the scientific study of matter and energy and how they interact with each other. This energy can take the form of motion, light, electricity, radiation, gravity . . . just about anything. Physics deals with matter from sub-atomic particles (i.e. the particles that make up the atom and the particles that make up those particles) to stars and even galaxies.

Or summing up

Physics is the subject that delves (explores) into our wonderfully and beautifully made universe and tries to describe things using laws.

How Physics Works

Experimental Physics

Physics uses the scientific method to formulate and test hypotheses that are based on observation of the natural world. The goal of physics is to use the results of these experiments to formulate scientific laws, usually expressed in the language of mathematics, which can then be used to predict other phenomena.

Theoretical physics

Theoretical physics is the area of physics that is focused on developing these laws, and using them to make new predictions. These predictions from theoretical physicists then create new questions that experimental physicists then develop experiments to test.

Aims of the Course (including SALs)

This is a practical course, which focuses on skills as well as content and knowledge. I am looking for students to confidently be able to visually inspect electrical equipment and have an idea of why an electrical appliance might not work. I am not expecting any student to be handling mains equipment, but it might be possible for them to check wiring and change a fuse. This must come with a health warning that getting it wrong can be fatal and if in doubt to ask. All work must be completed under adult supervision (and an experienced adult!)
SALs

- ◆¨ Measuring (current, voltage, length, resistance)
- ◆¨ Observing (effects of static current, effects of series and parallel circuits)
- ◆¨ Taking Readings (Including Using Alba)
- ◆¨ Line Graphs (plot a line graph of length of wire against resistance)
- ◆¨ Literacy Task (The Atom/ Definitions)
- ◆¨ Evaluating Experiments (Measuring I &V in series and parallel)
- ◆¨ Problem Solving (building circuits)
- ◆¨ Designing, Constructing, Testing & Modifying Solutions (fault finding and building circuits) as well

  as supplementary time to design and build circuits for the doll's house.

Terms To Avoid- Please!

Please avoid using the following terms wherever possible as it will cause trouble later
Electricity – What does this mean? it is more a group term and doesn't explain exactly what

you are describing. Use it for titles only and never for anything specific. (Ditto

for gravity)
Current flow – a current is a flow, instead try to use the term electron flow, or flow of charge.

Battery

Voltage in/ voltage through Current across

– the thing you use eg double A, triple A are cells and not batteries. A battery is a collection of cells
- voltage does not go in, or through. It is a measure of the energy drop per coulomb of charge as it passes around the circuit.

- current is a flow of electrons or charge and it travels through conductors.

Introduction to the course

This course covers the following outcomes
SCN:2.09, SCN:2.10 SCN:3.09, SCN:3.10a,

Potentially the following could be covered
SCN: 4.09a, SCN: 4.09b, SCN: 4.09c, SCN:4.10a, SCN:4.10b

The development of literacy skills plays an important role in all learning.

LIT 3-01a / LIT 4-01a, LIT 3-02a, LIT 4-02a, LIT 3-04a, LIT 4-04a, LIT 3-05a / LIT 4-05a, LIT 3-06a / LIT 4-06a ,, LIT 3-07a, LIT 4- 07a, LIT 3-09a, LIT 4-09a, LIT 2-10a / LIT 3-10a, LIT 4-10a, LIT 3-10a, LIT 3-13a, LIT 4-13a, LIT 3-14a /, LIT 4-14a, LIT 3-15a / LIT 4-15a, LIT 3-16a, LIT 4-16a, LIT 3-21a, , LIT 4-21a, LIT 3-22a / LIT 4-22a, LIT 3-23a, LIT 4-23a, LIT 3-24a, LIT 4-24a, LIT 3- 25a, LIT 4-25a, LIT 3-26a / LIT 4-26a, LIT 3-28a, LIT 4-28a, LIT 3-29a, LIT 4-29a

I develop and extend my literacy skills when I have opportunities to:

- communicate, collaborate and build relationship, ps
- reflect on and explain my literacy and thinking skills, using feedback to help me improve

  and sensitively provide useful feedback for others

- engage with and create a wide range of texts in different media, taking advantage of the

  opportunities offered by ICT

- develop my understanding of what is special, vibrant and valuable about my own and other

  cultures and their languages

- explore the richness and diversity of language, how it can affect me, and the wide range of

  ways in which I and others can be creative

- extend and enrich my vocabulary through listening, talking, watching and reading.

  My learning in numeracy enables me to:

  - develop essential numeracy skills which will allow me to participate fully in society
  - understand that successful independent living requires financial awareness, effective

    money management, using schedules and other related skills

  - interpret numerical information appropriately and use it to draw conclusions, assess risk,

    make reasoned evaluations and informed decisions

  - apply skills and understanding creatively and logically to solve problems, within a variety

    of contexts

  - appreciate how the imaginative and effective use of technologies can enhance the

    development of skills and concepts.
    MNU 3-01a (NB When they say accuracy I think they mean precision!), MNU 4-01a, MNU 3-03a, , MNU 3-03b,, MNU 4-03a,

    MNU 3-04a , MNU 3-07a, MNU 3-08a, MNU 3-11a, , MNU 4-11a, MNU 3-20a, , MNU 4-20a, MNU 3-22a
    Learning in health and wellbeing ensures that children and young people develop the knowledge and understanding, skills, capabilities and attributes which they need for mental, emotional, social and physical wellbeing now and in the future.
    Each establishment, working with partners, should take a holistic approach to promoting health and wellbeing, one that takes account of the stage of growth, development and maturity of each individual, and the social and community context.
    I can expect my learning environment to support me to:

  - develop my self-awareness, self-worth and respect for others

- meet challenges, manage change and build relationships
- experience personal achievement and build my resilience and confidence
- understand and develop my physical, mental and spiritual wellbeing and social skills

- understand how what I eat, how active I am and how decisions I make about my behaviour and relationships affect my physical and mental wellbeing
- participate in a wide range of activities which promote a healthy lifestyle
- understand that adults in my school community have a responsibility to look after me,

  listen to my concerns and involve others where necessary

- learn about where to find help and resources to inform choices
- assess and manage risk and understand the impact of risk-taking behaviour
- reflect on my strengths and skills to help me make informed choices when planning my

  next steps

- acknowledge diversity and understand that it is everyone's responsibility to challenge

  discrimination.

HWB 0-01a / HWB 1-01a / HWB 2-01a / HWB 3-01a / HWB 4-01a, HWB 0-03a / HWB 1-03a / HWB 2-03a / HWB 3-03a / HWB 4- 03a, *HWB 0-04a / HWB 1-04a / HWB 2-04a / HWB 3-04a / HWB 4-04a,* HWB 0-05a / HWB 1-05a / HWB 2-05a / HWB 3-05a / HWB 4-05a, HWB 0-07a / HWB 1-07a / HWB 2-07a / HWB 3-07a / HWB 4-07a, HWB 0-09a / HWB 1-09a / HWB 2-09a / HWB 3- 09a / HWB 4-09a, HWB 0-10a / HWB 1-10a / HWB 2-10a / HWB 3-10a / HWB 4-10a, HWB 0-11a / HWB 1-11a / HWB 2-11a / HWB 3-11a / HWB 4-11a, HWB 0-12a / HWB 1-12a / HWB 2-12a / HWB 3-12a / HWB 4-12a, HWB 0-13a / HWB 1-13a / HWB 2- 13a / HWB 3-13a / HWB 4-13a, HWB 0-14a / HWB 1-14a / HWB 2-14a / HWB 3-14a / HWB 4-14a, HWB 0-15a / HWB 1-15a / HWB 2-15a / HWB 3-15a / HWB 4-15a, HWB 0-16a / HWB 1-16a / HWB 2-16a / HWB 3-16a / HWB 4-16a, HWB 0-17a / HWB 1- 17a / HWB 2-17a / HWB 3-17a / HWB 4-17a, HWB 3-19a, *HWB 2-20a / HWB 3-20a / HWB 4-20a HWB 2-20a / HWB 3-20a / HWB 4-20a, HWB 2-21a / HWB 3-21a, HWB 3-23a, HWB 3-24a, HWB 3-33a, HWB 3-41a / HWB 4-41a*

Teachers INTRO

It would be good to wheel in the doll's house and show the students that this is wired up. If there is time at the end of the course the students can build something for the doll's house (this could be a homework task or to complete after the test)
The students are aiming to be awarded- the Ohm Comforts Official Members Badge, you can find sheets of these for printing in Resources

Whm CWmfWrts' Official Member

.
There are “particulars” of the Doll’s house with the story line that this house is up for sale and when sold a family wants some electricians to check the wiring and improve the electrical appliances in the house. (See Appendix 1 and 2)
There is a note in the root welcoming students as trainee apprentices.
Homework is a vital part of this course.
STUDENTS SHOULD NOT BE IN CLASS COPYING OUT NOTES, INSTRUCTIONS ETC. THIS SHOULD BE COMPLETED AT HOME AND PRACTICAL SHOULD BE COMPLETED IN THE CLASS. All the work will be up on the website www.mrsphysics.co.uk/bge **I give students permission to print out notes at home if required. Sign notes in and out for those students who do not have access to a computer, and a few sets can be printed for ASN students.**

This provides a great training for students on the purpose of homework. Any student who hasn’t completed homework can be placed in a corner and can write out the work whilst other students are completing the practical. This generally increases students who do homework as they want to be involved in dong the practicals

NB It is great when students work out the title of the course. I can’t take any credit for this it was Andrew Bowles who came up with the name.
I have used headings and broken things into lessons but some will take over a period. I will add this into the commentary.

Student INTRO

Welcome to Whm CWmfWrts a company set up to provide electrical services to those in and around Lockerbie. We are delighted that following your first Science test you have been accepted on the apprenticeship scheme.

The course is designed to give you a basic insight into electricity and how it can be used in the house. Your apprenticeship will take the following form

1. *A video to show why it is important to be careful around electricity.*
2. *A brief introduction to “what is this electricity anyway”*
3. *A check of building and drawing circuits using symbols.*
4. *Your assessment will be in several parts, one will be fault finding in circuits and one will be producing plans for a circuit plus a written test.*

On successful completion of your apprenticeship you will be invited to join the company and be given responsibility for a project.

LEARNING OUTCOMES FOR ELECTRICITY.

You should know that:

Electrical Safety

1. Electricity can be dangerous.
2. Recognise some of the dangers of electricity in the home and outside.

Atoms

3. All objects are made up of small particles called atoms.
4. Inside each atom there are three small particles called neutrons, protons, and electrons.
5. A proton has a positive charge.
6. An electron has a negative charge.
7. A neutron is uncharged or has a neutral charge.

How to make Electricity.

8. Electric charge can be made by rubbing two surfaces together.
9. A Van de Graff Generator produces electric charges.

Electric Current.

10. When electric charge moves we call it an electric current.
11. Current is a flow of charge (or electrons) around a circuit.
12. Materials that allow current through them are called electrical conductors.
13. Materials that do not allow current through them are called electrical insulators. 14. We use the symbol I to mean current.
15. Current is measured in amperes or amps.
16. Current is measured using an ammeter.
17. Ammeters are connected in series.
18. The symbol for an ammeter is
19. For electrons to flow there must be a complete circuit.
20. A multimeter can be set up to measure current, resistance or voltage.
21. When a multimeter is set up to measure current we call it an ammeter.

Resistance

22. Some materials have a high resistance and make it difficult for current to flow.
23. A continuity tester can be used to test for conductors and insulators.
24. Resistance is a measure of how difficult it is for the charges to move through an object. 25. The longer a wire the higher the resistance of the wire.

Voltage.

26. For most materials, as you increase the voltage the current increases. 27. Potential difference (p.d.) is often called voltage.
28. p.d. is the push that makes the charges move around a circuit.
29. Voltage is measured in volts.

A

30. Voltage is measured using a voltmeter, symbol V,_. 31. Voltmeters are connected in parallel.

Drawing Circuits.

V

32. Circuit symbols are used to show how circuits can be built.

33. The circuit symbol for a cell, switch, bell, ammeter, voltmeter, lamp, power supply, resistor, wire, connected wire.
34. Make sure that you can draw circuits using the proper symbols and following the rules for drawing circuits.

Series and Parallel Circuits

35. The two types of circuit are called series and parallel.
36. In series circuits the current is the same all round the circuit.
37. In parallel circuits the current splits up and some goes down each branch.
38. In series circuits the voltage across the components adds up to give the voltage of the supply.
39. In parallel circuits the voltage is the same across each branch.
40. The current drawn from the supply increases the more components are connected in parallel.
41. When lamps are added in parallel the current drawn from the supply increases. This is because the

    overall resistance of the circuit is reduced.

42. I can help to design simple chemical cells and use them to investigate the factors which affect the

    voltage produced.

Additional Learning Outcomes

43. Using experimental evidence, I can place metals in an electrochemical series and can use this information to make predictions about their use in chemical cells. SCN 4-10a
44. Using a variety of sources, I have explored the latest developments in chemical cells technology and can evaluate their impact on society. SCN 4-10b

The Effects of a Current

45. The flow of electric current through a conductor produces several useful effects, heat, light, magnetism, and chemical effects.

Ohm's Law-

46. I can try the Ohms Law task, (a level 4 outcome and there is a sheet provided to help) This could form a Nat 4 or 5 outcome 1. V=IR (Voltage = current multiplied by voltage)

LESSON PLANNING- ORDER

Order / Lesson No.	***Content***	***Homework***	***Resources***
1	*Intro to course (WHAT IS PHYSICS), issue outcomes,* *Intro to Whm CWmfWrts Safety, video*	*ELECTRICTY title page* *The Atom sheet* *Locate the main electrical switch to turn off all electricity to the house. This is a red large switch.*	*http://dingo.care2.com/cards/flash/5409/galaxy.swf* *(NB this contains a rude word. Please warn the students and cough loudly at the end) https://www.youtube.com/watch?v=p_o4aY7xkXg* *http://htwins.net/scale2/?bordercolor=white* *Doll's House, with wiring, particulars sheet* *Atom sheet- I'd like to get this up to GLOW or the website and students download at home. Give copies for those who don't have computer access. www.mrsphysics.co.uk* *http://www.twothirtyvolts.org.uk/electrical-safety/around-your-home/* *http://www.classtools.net/education-games-php/timer/*
2+3	*Go through atom homework.* *Static, what is static, experiments including the VdG*	*Locate the mains switch in your home* *write up the experiment, mainly as pictures with small amount of text..*	*Static experiments sheets.* *http://www.kasuku.ch/pdf/monde_etrange_atomes/EN_amazing_world_atoms.pdf* *Order electrostatics tray (rods, watchglasses, salt and pepper mixed, loo roll cloths etc)*

Order/ Lesson No.	***Content***	***Homework***	***Resources***
4	*What is a circuit?* *Testing for conduction starting with a torch lamp* *(or go from what is a circuit to why draw circuit symbols)*	*Draw Symbols and Circuits*	*Build a circuit with one lamp (2.5V), 1 cell and 1 wire only. Add in holders, add in switch,* *Equipment: Lamps, cells, leads, switches. If possible get a box of cells rather than removing them from holders which wrecks the springs.* *Starting Science Book 1 pp 85+ Marbles (all the same size) Circuit symbol sheet. (website)*
5	*Conductors & insulator*		*Tray of conductors and insulators. Cells lamps, leads and switches. SAFETY Do not allow students to go near sockets or electrical appliances*
6	*Current Voltage & Resistance (written exercise + quiz, terms and words)*	*Learn 16 words and definitions in word list*	*Definition and word boards . NB Do NOT give the lower ability students the definitions on the cards, this is a much harder task. For most students add the word on a card to the definition on the board. Activinspire definition sheet, white boards if required.*
7+8	*Meters (effect on resistance and current of long wires)*		*Meter table (showing ammeter, voltmeter and ohmmeter)* *Meter sheet showing the connections. Both of these can be cut out and stuck in. Conductors and insulators tray can be used as previous.*
8,9	*Building Circuits briefly introduce series and parallel*	*Meters*	*Laminated fault finding cards, one per group for checking their circuits.* *ppp of Building circuits for if you want to keep students together, or better still give them the small printed sheets with the 7 circuit descriptions on.* *3 xLamps 2 x switches 7x leads 2 x cells (per group) + spares*
Order/ Lesson No.	***Content***	***Homework***	***Resources***
9,10	*Explanation of series and parallel from the model*	*Review Definitions start revision*	*Flipchart paper, or board.*
11	*Measuring Current and Voltage in series and parallel*	*Electrical Dominoes Revision*	
12	*Fault finding*	*Revision*	*11 fault finding boards and repair kits (please check in and out at the end of each lesson), fault finding laminated sheets, multimeters*
13	*Fruity Batteries*	*Students can try to bring in some fruit or veg before this lesson and have some in reserve*	*Fruit and veg, different metals as electrodes, croc clips, leads.*

14	*Assessment Introduction to the Dolls House*	*Give students opportunity to build something for the doll's house (do not move, or change anything already there), things created include a bbq, fridge, revolving microwave, door bell.*	*Tests in H208 (please return after use)*
15	*Go through test + start design and make or Ohm's Law*	*Plan for the design and make*	*For Ohm's Law, ceramic mounted resistors, leads, power supplies and 2 multimeters per group*
16+	*Students design and make*		*Motors, wires, cells, potentiometers you might want to look at the electronic boards etc.*

LESSON 1-What is Physics?

AIM fo LESSON 1

1. 2. 3.

I have an understanding of the subject of Physics I know the types of topics that make up Physics I understand I am responsible for my learning.

S A

L

- **Express views**
- **Present an argument • Hypothesising**

Introduction- This may well take up to 1 lessons

Task 1 for students

1) Write the homework in your jotters
ELECTRICITY TITLE PAGE complete for next period
The Atom Sheet: Give one week's notice to complete this. The answers are in the sheet (literacy task)

Task 2 for students

2) What is Physics?
Brainstorm- draw a bubble in books students write what they think Physics is. See how many of them fail to write the word ELECTRICITY (not very thoughtful, why would I give them homework if it is not relevant).

Task 3 Teacher Questioning

Drop a pen and ask why it falls, most will say it is gravity but ask them what that is? (I am sure I did a video for this last year but it will be rubbish as I am not an actor!). Get them to talk to their parents about it. Most will not have a clue or will say it is because the Earth sucks or spins. The real reason is because of its mass. Anything that has mass attracts other things so everyone in this room is attractive- ask what the difference is between us and the Earth, Earth more massive. If we were as massive as the Earth we would pull things towards us which could be embarrassing for us all especially if we were bending down.
https://www.youtube.com/watch?v=p_o4aY7xkXg (only for the brave)

Do we feel like we are moving? No, well how do we have day and night? Earth is spinning? Which way? Sun rises in East and sets in the west so we must be turning anticlockwise as we stand. That means we are going pretty quickly.

Circumference/24 hours= speed in miles per hour

pd/24
3.14´ 7,918/24 = approx. 1000 mph

Obviously we are travelling slower than that? Why? Less distance

http://dingo.care2.com/cards/flash/5409/galaxy.swf
http://htwins.net/scale2/?bordercolor=white
Plenty of other discussion ideas just ask me about some or make some up.
Also can students stick a bit of tin foil on the front of their jotters with a label "This person is responsible for your learning". This came from an idea I had whilst at CX, where the mirrors in the bathroom said this person is responsible for your safety. Students can't and shouldn't blame anyone else for their failure to learn.

Task 4 Student task, uses of electricity

This is a really interesting task to find out about your students. It is amazing what they can learn. I tend to tell them that I will adopt one of them if they pass the test. Ask the students to write down 30 uses of electrical current. Time with classroom tools.
http://www.classtools.net/education-games-php/timer/

You'll get farmers choosing miling machines, girls picking hair driers, all picking mobiles and computers and occasionally you'll get one student in a class that record such things as irons, washing machines and tumble driers! They pass the test. It gives a good indication of who is spending what time on their computers and square boxes.

LESSON 2 + 3- Safety & Static current

AIM for LESSON 2

1. I know that using electrical items can be dangerous.
2. I know how to be safe with electrical items
3. I can recognise some of the dangers of electricity in the home and outside.
4. I know how to generate static electricity
5. I know that electrical charge can be made by rubbing two surfaces together.

6. I know that a Van de Graff Generator produces electric charges.

• Risk Assessment

S A

L

This lesson, which may take between 1 and 2 periods covers Safety of Electrical Current and generating static electricity in the lab. It carries on nicely from the last lesson, so if you are really short of ideas you can ask them about safety. If students have a clear idea that static and current are the same thing, just one is flowing and the other isn't it goes some way to clearing up the problems that arise later, that electricity is really energy carrying electrons.
Possible breakdown of time depending on when you see students

1. Safety + VdG lesson 2. Review Atom homework + Static Experiments
2. Safety + review of atom homework lesson 2: Static Experiments then VdG

What is "Electricity" and why we shouldn't use that word

The term electricity can mean so many things it is not a very scientific word so is best avoided. We usually use it to mean electrical energy or electrical current but can be used to describe voltage . As we cannot be sure what you mean by the term we will use it only for the title of the block and not for any other context. I play BUZZ where if I use the term in the wrong context students can buzz to remind us all that it isn't appropriate- usually works well, or use the term "Electricity Topic"

Electrical safety videos

It is vital before students start that they have a good healthy respect for the topic of electricity (!). We don't want students terrified but we do need to get over the point of the damage that can be caused if things go wrong or if it is not treated sensibly.

We will not have time to watch ELECTRICAL GRAFFITI but we might do a few lunchtime viewings. We should be able to see some clips of electrical safety but there are other good ones on the web. If you don't get to see all of these in the class try viewing some at home, but DO NOT TRY ANY OF THE STUNTS AT HOME- THEY COULD KILL!

Here are a few I have selected, some are American so the plugs might look different but still the same rules apply. 1. http://www.twothirtyvolts.org.uk/electrical-safety/around-your-home/

(use this in the first instance) 2. http://www.esc.org.uk/

Lesson 2 + 3. This may take at least 2 periods but can be started period 1

3. http://video.google.co.uk/videosearch?hl=en&q=electrical%20safety&cr=countryUK%7CcountryGB&um=1&ie=UTF- 8&sa=N&tab=wv#
4. http://www.youtube.com/watch?v=l-wXyw0tvSA
5. http://www.veoh.com/browse/videos/category/educational_and_howto/watch/v18592895eRqz2Net
6. http://www.youtube.com/watch?v=ay_Wzyec36A&feature=player_embedded#
7. http://www.youtube.com/watch?v=PvPmuReff6U
8. http://www.youtube.com/watch?v=rTbBqGFdJF4
9. http://www.break.com/usercontent/2008/11/The-Electrical-Safety-Foundation-International-Launches-607009.html
10. http://www.5min.com/Video/Learn-About-Electrical-Safety-61996853
11. http://www.metacafe.com/watch/2031644/electrical_safety_foundation_international_warns_consumers_about_the_ dangers_of_counterfeit_electrical_products/
12. http://video.google.co.uk/videosearch?hl=en&q=electrical%20safety&cr=countryUK%7CcountryGB&um=1&ie=UTF- 8&sa=N&tab=wv#
13. http://www.escweb.org.uk/news-and-events/latest-news/View-Our-Television-Advert-id-31.html
14. http://www.youtube.com/watch?v=CYhILq1naZo

Important safety points

1. Do not mess around with “electricity”. It can be fatal.
2. Main Dangers of electricity

   a. Electric shock and burns from contact with electricity
   b. Exposure to electrical arcing
   c. Fire from faulty electrical equipment or installations
   d. Explosion due to electrical equipment or static electricity igniting flammable vapours or dusts

3. All wiring should be inspected to make sure the wires are not frayed
4. Never put things into sockets, metal or otherwise, only fully compliant insulated plugs.
5. Never put electrical items in damp places (it is illegal to have 13A sockets in the bathroom, and other sockets should be isolated from people, eg shower switches are generally pull cords, etc)
6. Don’t overload sockets, this can cause a fire. The maximum load in one socket should be 3000 W. Students can check this by looking at the rating plate on their appliances. If the total in one socket is more than this value then something must be removed.
7. Items that produce heat use more electrical energy ever second.
8. Don’t put items in the toaster to eject toast.

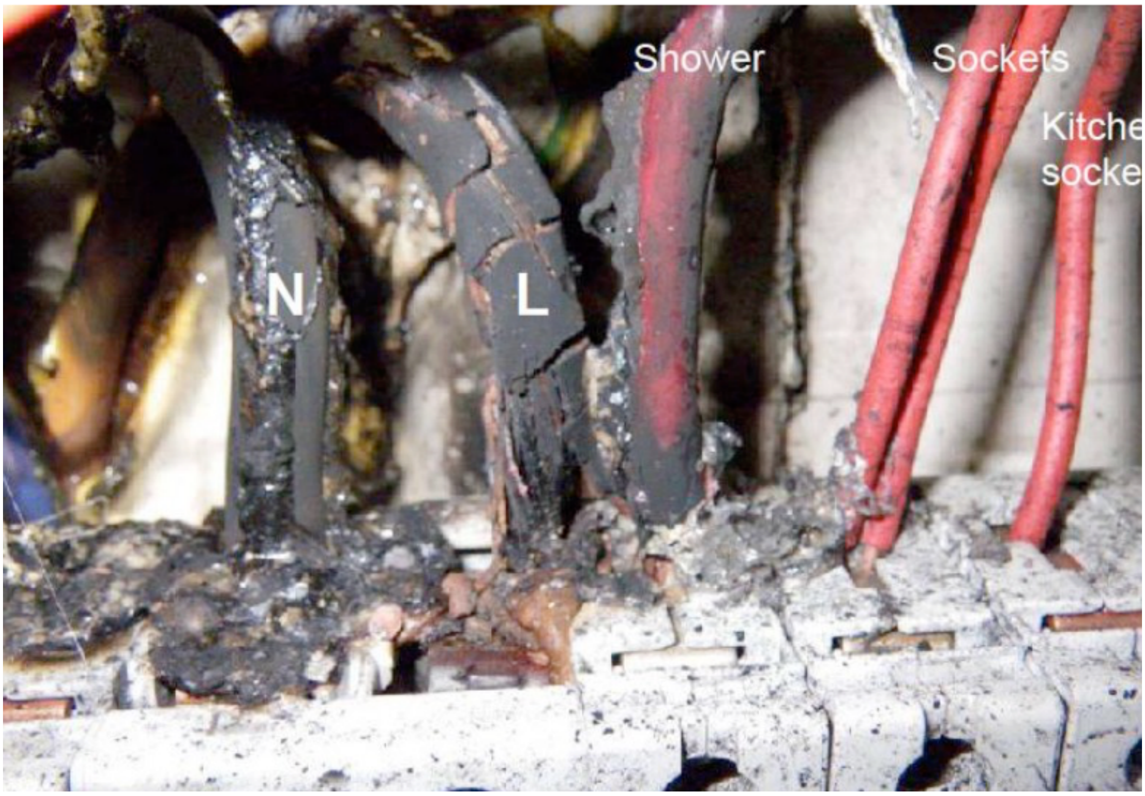
9. Outside stay away from sub stations, pylons and other electrical equipment. Much of it is high voltage and can kill.
10. Please note it is the current that kills rather than the voltage across a person. Usually a high potential difference will cause a high current but this is not always the case. For example you may get a p.d. of 1000 V across the VdG but the current is miniscule so should not cause harm.

I tell the story of a young woman who had a baby in the buggy. She came home after shopping to find her kitchen flooded from the washing machine. I ask the students what they should do. Most say switch off the electricity and I say this is above the washing machine; is this OK? What happened was the young lady walked through the water to switch the electricity off and was electrocuted. Her 18 month old called the alarm from the screams. The lady ought to have switched off the electricity at the MAIN ELECTICITY box. If this wasn’t accessible they should ring the electricity company and ask for it to be disconnected as an emergency. Wearing wellies, is too risky and should not be attempted.

Contact with Live Parts can result in:

- ◆ˆ Shock leading to cardiac arrest and death (electrocution)
- ◆ˆ Non-fatal shock can cause other injuries
- ◆ˆ Current through the body can cause deep burns
- ◆ˆ Current through the body will depend upon the voltage & resistance of the circuit, including body

  resistance



See ROSPA. For details

http://www.rospa.com

The Atom

If this is the following day for the atom and students have not had time to complete this task then do conductors and insulators lesson first and then come back to statics
Go over the homework for the atom and make sure that students have an understanding of the atom and that it contains several parts. They should be aware that diagrams of the atom are never to scale. I was told that if the atom was a football field the nucleus would be the size of a pea. (It is a good idea to ask them what they think the size would be, eg, goal, centre circle, whole midsection, football etc)

ATOMS make up all materials. There are 3 parts to atoms. They are called neutrons, protons & electrons. The protons are positively charged. The electrons are negatively charged and the neutrons have no charge ***or neutral****. The centre of the atom is called the nucleus . This contains the protons and neutrons . The electrons move round the centre of the atom. It is the electrons that can be removed from the atom and make electricity . Atoms usually have 0 charge and are called neutral because the number of protons in the nucleus is equal to the number of electrons in the orbits. However, rubbing one object on a different object can remove electrons* *from atoms. When the electrons are "stolen" and made to move we have an electric current. We sometimes call these electrons charges because they have a negative charge.*

Naff Joke
A neutron goes into a pub and asks for a pint and asks the landlord how much it will cost. The landlord replies, for you "no charge!"
For the bright students you might want to tell them that Atom means indivisible as people originally thought this was the smallest thing there was. Then we discovered protons and electrons and thought they were the smallest thing there is, now we've found quarks, so who knows where we'll end up!- bright students could research this. CERN do some great teaching resources.

To be consistent across the Sciences, it has been requested we use the term neutral as it fits with remembering the term neutron. A particle can be neutral or have no charge it cannot be neutrally charged. Please make sure they understand this term, but we will all use this.

How to generate static electricity in the lab

There are a range of experiments that can be completed to generate static current or charge. When we rub too different materials electrons can be ripped off one of the materials and be stored on the other material. If the material is an insulator then those electrons will remain on the material. If they are a conductor they will move through the material and it will not remain charged. Cashmere and fluffy jumpers charge the best. Usually polythene charges up negatively, acetate positively. Acetate never charges as well as the polythene. Charging is most effective if it is in one direction and gripped hard, along the elbow.

Electricity Types

Background information Static and Current Electricity

NOTE: If you attempt to do any experiments which involve electricity – NEVER use the current from the mains. It is very powerful and very dangerous. You should only use cells for electrical experiments., unless told by your teacher.

There are two types of electricity:

1.) Current Electricity – is caused by tiny invisible things called electrons that move through metal. This flow is called an electric current. Objects that need current electricity (moving electricity) are powered by batteries or by electricity which travels along wires from a power station. The circuit is completed by a switch, which turns the appliance on. When the switch is turned off, the circuit is broken and the appliance is turned off, no electrons flow around the circuit.

Many objects that we use every day are powered by electricity – from computers and hairdryers to lamps and washing machines.

2.) Static Electricity - this type of electricity stays in one place. Static electricity is produced when some materials are rubbed together. Static electricity is the result of an imbalance between negative and positive charges in an object. These charges can build up on the surface of an object until they find a way to be released or discharged. One way to discharge them is through a circuit.

How does static electricity work? Static electricity happens when there is an imbalance between negative and positive charges in objects. It causes crackles when you comb your hair and makes dust stick to television screens. Static electricity experiments work best on a dry day.

Lightning is caused by a natural build-up of static electricity in clouds. The lightning strike is just a giant spark of electricity. Have you ever walked across the room to pet your dog, but got a shock instead?

The rubbing of certain materials against one another can transfer negative charges or electrons. For example, if you rub your shoe on the carpet, your body collects extra electrons. The electrons cling to your body until they can be released. As you reach and touch your furry friend, you get a shock. Don't worry; it is only the surplus electrons being released from you to your unsuspecting pet.

Have you ever taken your hat off on a dry winter's day and had a "hair raising" experience?

As you remove your hat from your head, electrons are transferred from the hat to your hair, creating and re-arranging your interesting hairdo. Remember, objects with the same charge repel each other. Because they have the same charge, your hair will stand on end. Your hairs are simply trying to get as far away from each other as possible. Combs attract bits of paper. Clothing "clings" to your body because of static electricity.

Have you ever made a balloon cling on to a wall after rubbing it against your clothes?

When you rub a balloon against your clothes and it sticks to the wall, you are adding a surplus of electrons (negative charges) to the surface of the balloon. The wall is now more positively charged than the balloon. As the two come in contact, the balloon will stick because of the rule that opposites attract (positive to negative).

All physical objects are made up of atoms. Inside an atom are protons, electrons and neutrons. The protons are positively charged, the electrons are negatively charged, and the neutrons are neutral. Therefore, all things are made up of charges. Opposite charges attract each other (negative to positive). Like charges repel each other (positive to positive or negative to negative). Most of the time positive and negative charges are balanced in an object, which makes that object neutral.

For each of the following experiments that you try draw a diagram or diagrams to show what you did and write a conclusion explaining your observations

Static electricity experiments

1. Stuck on You A sticky experiment!

Materials you will need:
• A Balloon
• Strong Lungs
• A Woollen or Nylon Sweater (Jumper)

Steps:

1. *Blow up the balloon and tie the end so that the air does not escape.*
2. *Take the balloon and rub it vigorously against your jumper/sweater or your head of hairs about ten times.*
3. *Now hold the balloon against your jumper/sweater or hairs for a minute.*
4. *Let go of the balloon. What happens? Does it stick?*

When a balloon and a jumper/sweater or hairs are rubbed together; each will gain a different type of electrical charge. The balloon becomes a negative charge and the jumper/sweater or hairs becomes a positive charge. Opposite charges attract each other.

2. Bending Water Experiment

Materials you will need:

◆¨ *A Plastic Comb or rod*
◆¨ *Woollen Jumper or cloths* ◆¨ *Running Tap (Water)*

This is a cool experiment! Steps:

1. *Rub the plastic comb against your jumper or comb through your hair around ten times.*
2. *Turn the tap on so that it has a slow, steady stream of water.*
3. *Place the comb close to the water (don't let the comb touch the water).*

3. Resisting Balloons

Materials you will need:

- *Tape*
- *Scissors*
- *Door Frame*
- *Two Balloons*
- *String/Thread*
- *A Woollen Sweater/Jumper*

Steps:

1. *Cut two equal lengths of thread/string and tape them to the top of a door frame in the middle about 1 inch or 2.5 cm apart.*
2. *Blow up the balloons and tie each end so that the air does not escape.*
3. *Tie each of the blown up balloons to the end of each thread/string so that they are hanging at the same height and are resting next to each other.*
4. *Rub each of the balloons with the woolly jumper/sweater to charge them (one at a time).*
5. *What happens when you let them go? How do they react to each other?*

Both of the balloons have become negatively charged once they have been rubbed with the woollen jumper/sweater and will push each other away. Items that are made up of the same material will always take on the same charge. If you have a matching charge of static electricity in like items, they will repel each other just like the same poles of magnets will repel each other.

Try to bring the two balloons together after they have been rubbed with the woollen sweater/jumper. What happens when you try to bring the balloons together?

Place your hands in between the two balloons, does something different happen?

4a. Rising Tissue Paper

This is a fun experiment to watch as the tissue paper is pulled up by the charged comb/pen. Materials you will need:

- *Scissors*
- *Tissue Paper*
- *Woollen Jumper/Sweater*
- *A Plastic Comb/Pen*

Steps:

1. *Cut up some small pieces of tissue paper.*
2. *Charge up the comb/pen by rubbing it against a jumper/sweater or combing through your hair about ten times.*
3. *Hold the comb/pen over the small pieces of tissue paper.*

4b. Rising Tissue Paper

Materials you will need:

- *Ruler*
- *Tiny pieces of colourful tissue paper*

- *Several objects available that you can rub the ruler with that will prevent it from picking up the tissue paper (paper,*

  metal, water)

- *Several objects that will enable you to pick up the tissue paper (fake fur, silk)*

  Steps:

1. *Ask the students if they think you can pick-up the tissue paper with the ruler.*
2. *Try to pick up the pieces of paper with a ruler that has not been charged.*
3. *Next, ask the students if they can think of what you could do to the ruler to enable it to pick up the pieces of paper.*
4. *Use the materials listed above to try to demonstrate to the students what materials will charge the ruler and which ones won't.*

Note: You must neutralize the ruler each time before you rub the ruler with a new object. You can neutralize it by rubbing on your shirt or wetting it with water.

5. Charged or Not Charged - Balloons

Materials you will need:

·Tape
·Scissors
·Two Balloons
·String/Thread
·A Woollen or Nylon Sweater (Jumper) Steps:

1. *Inflate both balloons so they are the same size. Tie a knot in the neck of each balloon so that the air does not escape.*
2. *Tie one end of the string to one of the balloons.*
3. *Using tape, secure the free end of the string to the edge of a table.*
4. *Charge the second balloon by rubbing it with the wool scarf.*
5. *Hold the charged balloon near, but not touching the hanging balloon.*
6. *Observe the motion of the hanging balloon.*

Before rubbing, like all materials, the balloons and the wool scarf have are neutral. This is because they each have an equal number of positively charged subatomic particles (protons) and negatively charged subatomic particles (electrons).

When you rub the second balloon with the wool scarf, electrons are transferred from the wool to the rubber because of differences in the attraction of the two materials for electrons. The balloon becomes negatively charged because it gains electrons from the wool, and the wool becomes negatively charged because it gains electrons from the wool, and the wool becomes positively charged because it loses electrons.

When the negatively charged balloon is brought near the neutrally charged hanging balloon, the electrons on the surface of the hanging balloon move away because like charges repel. This leaves the surface facing the charged balloon more positive. Since opposite charges attract, the positive charge on the surface of the hanging balloon is attracted to the negative charge on the hand-held balloon. This attraction is strong enough to move the hanging balloon.

6. Charging up a Lamp

Materials you will need: • A Dark Room
• Fluorescent Light Bulb • A Comb/Woollen Scarf Steps:

1. *Go into a dark room with the light bulb and the comb (woollen scarf).*
2. *Run the comb through your hair around 20 times. You could rub the comb over a woollen scarf for the same effects.*
3. *Place the comb on the metal end of the light bulb and watch as the filament in the bulb lights up.*

The friction between your hair and the comb causes electrons to travel from your hair to the comb. This causes your body to become positively charged and the comb becomes negatively charged. With the comb being charged, it discharges into the light bulb causing the bulb to emit the small pulses of light.

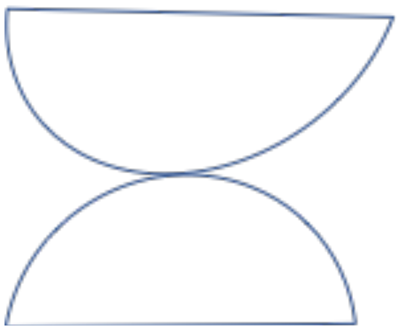
7. TwoCharges

Place one watch glass upside down on top of another one. The top one should be free to rotate. It can be achieved with one, but it is not usually as effective

Charge a rod with a cloth and carefully place it onto the watchglass leaving one side overhanging. DO NOT touch the rod as it is placed on the watchglass as it will discharge.

Charge another rod and bring it close to the charged rod (do not touch it)

Depending on the charge of the rod the other rod should rotate towards or away from the rod. Try similar and opposite rods. Always use the same cloth to rub each of the roads. This shows that there are two types of charge original with the names – positive and negative.



8. Separating Salt and Pepper

Materials you will need:

- *One teaspoon of Pepper*
- *One teaspoon of Salt*
- *A piece of Wool or Fake Fur*
- *Plastic petri dish or Sheet of Paper and a Clear plastic ruler*

Steps

Using a Sheet of Paper

1. Have the students measure out one teaspoon full of salt and one teaspoon full of pepper onto the sheet of paper.

2. Use a pencil's eraser top or pen top to mix the salt and pepper together.
3. Have the students take the plastic ruler/rod and rub it with the wool/fake fur.
4. Approach the pepper with the ruler/rod from above slowly. The pepper will begin to jump onto the ruler. As you get closer to the mixture, the salt will eventually begin to jump to the ruler. The pepper will jump to the ruler/rod and stick.

Using a Petri Dish

1. Have the students measure out one teaspoon full of salt and one teaspoon full of pepper into the petri dish.

2. Place the cover on the petri dish and mix well by gently swirling.

3. Have the students rub the top of the petri dish with the fur. Turn the petri dish over for a few seconds and then turn it back to the original position. The pepper should stick to the top of the petri dish.

The uncharged pepper particles were attracted to the petri dish or ruler as opposite charges were induced in the pepper. Since pepper is lighter than salt, it takes less effort for pepper to overcome the force of gravity.

Rubbing the plastic surface with the fur/wool caused the plastic surface to become charged with static electricity. (There was an excess of electrons left on the plastic from the fur/wool).

Since pepper is lighter than salt, it takes less effort for pepper to overcome the force of gravity.

You can place both the salt and pepper into water. The pepper will float and the salt will sink. You can skim the top of the water and remove the pepper.

Using the stencil allowed rubbing the petri dish lid at certain confined areas. Only those areas that were touched with the fur/wool were charged.

8b. Stencilling in Salt and Pepper
Extensions
If using a petri dish, you can expand on this lab. Steps:

1. *Place the salt and pepper back in the bag and clean the petri dish.*
2. *Start with a clean, dry petri dish.*
3. *Next, let add a pinch of pepper to the petri dish.*
4. *Place the lid back on the petri dish.*
5. *Take a piece of paper and cut it the same size as the lid to the petri dish.*
6. *Once this is done, have them cut out a stencil from this paper.*

7. *Next, hold the stencil on the lid and rub the open area (the cut-out area) with the fur.*
8. *Remove the stencil and turn the petri dish over for a few seconds and turn it back over again to the original position.*
9. *You should see their stencil of pepper sticking to the cover.*

Don't even try to try all these experiments. If you feel brave this is best done as a circus.

9.Charging cornflakes , charging balloons

- *Cornflakes, suspended on thread*
- *Balloon*
- *Clamp stand, bosshead and clamp*

Rub the balloon on your hair or a cloth, bring it towards a hanging cornflake and see what happens.

Then suspend two balloons on thin threads and hang from clamps, be sure the metal clamps are as far from the balloons as possible (maybe clamp two metres sticks etc)

Rub the balloons on your hair and gently release then without touching the part that you rubbed. The balloons should repel.

Alternative Teacher Led demonstrations

1. Try to stick a rubber balloon on the ceiling or wall after you have put electric charges (remember that charges are positive or negative parts of an atom) on it.
2. Now answer the questions in your jotter.
    1. What do you think affects the length of time the balloon sticks to the wall?
    2. Explain how you put electric charge onto the balloon.
3. Use a plastic comb, ruler or rod to pick up some small pieces of paper.
4. Now answer the questions in your jotter.
    1. Can you make the comb pick up more paper?
    2. If you could pick up more paper explain how you did it.
5. Describe what happens when an electrically charged plastic pen is held near a thin stream of water.
6. Rub a balloon on your jersey and try to make your hair stand on end.
7. Now answer the questions in your jotter.
    1. Can you give a reason for why this happens?
    2. Does your hair standing up depend on whether you have rubbed the balloon?
    3. Is your hair being pulled towards the balloon or away from it?
8. If you have time or are waiting for apparatus complete the following task in your jotter. Read and answer the questions on page 84 of Starting Science Book 1.
9. The following task must be completed with your teacher. Read the following paragraph and then copy and complete the summary to check that you have understood the work.
10. When you rubbed the rod against a cloth or your jumper some of the outer electrons from the materials were 'stolen' by the rod. This means that the rod has less electrons and so is negatively charged. The material has lost some electrons and so is positively charged The material and the rod are likely to remain like this for some time. This is because the materials from which they are made do not allow charges to move or escape.

Van Der Graff

NB There is an instruction sheet that the students will be able to download explaining how they can make their own VdG generator. It has been checked by Gregor Steele. No one has made one yet. http://practicalphysics.org/van-de-graaff-generator-basics.html
http://practicalphysics.org/Van_de_Graaff_generator_apparatus.htm

Van de Graaff generator safety

Van de Graaff generator demonstrations can provide useful insights into electrical phenomena, which are at the same time memorable.

- It is essential the Van de Graaff generators for school science are obtained through reputable school science equipment suppliers. The electrostatic energy stored by the sphere should not exceed 0.5 J.
- Do not add devices to the sphere that increase the capacitance.
- Van de Graaff generators with mains powered pulleys must be electrically inspected and tested in the

  same way as other mains powered equipment.

- When carrying out the hair-standing-on-end demonstration, do it with one person at a time. After the

  demonstration, to avoid a sudden discharge, the person should take their hand off the sphere and touch the surface of a wood bench top (avoiding metal fittings such as gas taps). Alternatively, hand the charged person a wooden metre rule. After a few moments, they will be discharged.

- **It is not advisable for people to participate in practical work with Van de Graaff generators if they have heart conditions, or a pacemaker, or other electronic medical equipment fitted.** Neither should they participate if they have epilepsy. YOU MUST ASK AND CHECK AT THE START OF EVERY LESSON.
- The electrical discharge from a Van de Graaff generator can wreck electronic circuits, so equipment such as computers and instrumentation with electronic circuits should be kept well away.

  The Van de Graaff generators designed for schools are usually the triboelectric type – these are the most suitable. The transfer of charge is achieved by a rubber belt driven by a plastic pulley, with an arrangement of metal combs at either end of the belt. Charge is transferred to a metal sphere – a capacitor – and very high voltages are achieved between the sphere and ground, typically in the range 200 kV to 300 kV.

  Using a Van de Graaff generator, one is quite likely to receive a short shock by accidental or intentional contact with the charged dome. An enquiry to CLEAPSS has revealed no recorded incident of direct injury caused by shocks from the correct use of school Van de Graaff generators. However, some people are more sensitive than others and can find the shocks very unpleasant and painful. For this reason, only volunteers should take direct part in the practical work.

  The shock is a single unidirectional pulse of short duration - The current flowing and energy transferred should be well below that which could cause any risk of ventricular fibrillation.

  Generally speaking, sphere diameters of Van de Graaff generators should be about 20 cm or less.

Van de Graaff generator - the basics and the background (skip if you don't find this hair raising!)

PRINCIPLE OF OPERATION

Some insulating materials when separated from the surface of others, leave those surfaces electrically charged, each with the opposite sign of charge and with a high potential difference (p.d.).

A machine to make charges was invented in 1929 by a young American called Van de Graaff. Huge machines, some over 30 m high, based on his ideas have been built to produce extremely high potential differences.

BELTS AND ROLLERS

A flexible belt made from an insulating material and running continuously over two rollers can, by the same process, produce a supply of charge where the surfaces separate. The two rollers have to have different surfaces (often acrylic and metal) and together with the belt-rubber, are chosen by experiment.

COMBS

Charges are "sprayed" on to and removed from the moving belt by "combs" situated adjacent to the rollers. Actual contact between the combs and the belt is not essential because of the

high potential differences. Combs can be simply a stretched wire, or a sharp or serrated edge: action depends on very high potential gradients due to their small radii (similar action to lightning conductors).

The lower comb is maintained at or close to earth potential and is a drain for negative charge, leaving the belt with positive charges that are carried up to the top comb.

COLLECTING SPHERE

The top comb is connected to a collecting sphere which, having inherent electrical capacity (proportional to its radius) will collect and store the charge on its outer surface until discharged either by breakdown of the surrounding air as a spark, or by conduction to an adjacent earthed object.

CHARGING CURRENT

So long as the belt continues to move, the process continues, the drive (motor or manual) supplying the power to overcome the electrical repulsion between the charges collected on the sphere and those arriving on the belt.
The charging current is usually a few mA and potential difference achieved by "junior generators" will be 100-150 kV and by "senior" generators up to about 300 kV.

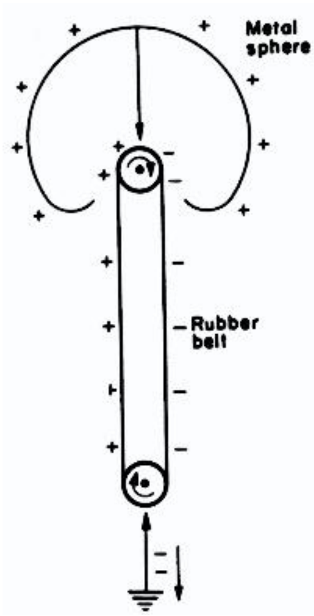
THE WHOLE APPARATUS

The mechanical arrangement of the belt/roller system is very simple. The lower roller is driven either manually or by motor. The motors, control switches and mains input socket are housed in a metal or plastic enclosure, although some junior models have used a transparent plastic cake-cover.

The support column for the collecting sphere can be a simple PVC plastic rod or acrylic tube or a pair of acrylic strips with separators. In some models the belt is enclosed within a plastic pipe with "windows" along its length. Not all generators have means of adjusting the separation of the upper and lower rollers i.e. the belts have to be tailored for a particular machine.

Since the diameter of the collecting sphere determines the maximum p.d. (voltage) achievable, large spheres are mounted on taller columns to be more remote from the earth motor and control box.

Machines are usually supplied with a "discharger", often another, smaller, sphere mounted on a metal rod that has to be earthed to draw sparks from the collecting sphere.



Demonstrations and accessories

Certainly the Van de Graaff generator can produce striking demonstrations. The usual experiments are:

***Faraday's cylinder** to show electric charge resides on the outer surface of a charged hollow conductor.*

***Bouncing ball** Suspend a conducting ball a non-conducting thread. When the ball touches the charging sphere, it will become charged and be repelled away from the sphere. If the ball is then allowed to discharge (touching an earthed surface, or leaking charge to the air) it will be attracted once more to the sphere, to be recharged ... and so the process continues.*

***The head of hair** is another demonstration of repulsion. Real hair or shredded paper strips bunched at one end are used and provide a sensitive means of detecting charge.*

An apparatus note on the Van de Graaff generator gives information about good housekeeping and repairs.

Van De Graaff Demonstrations

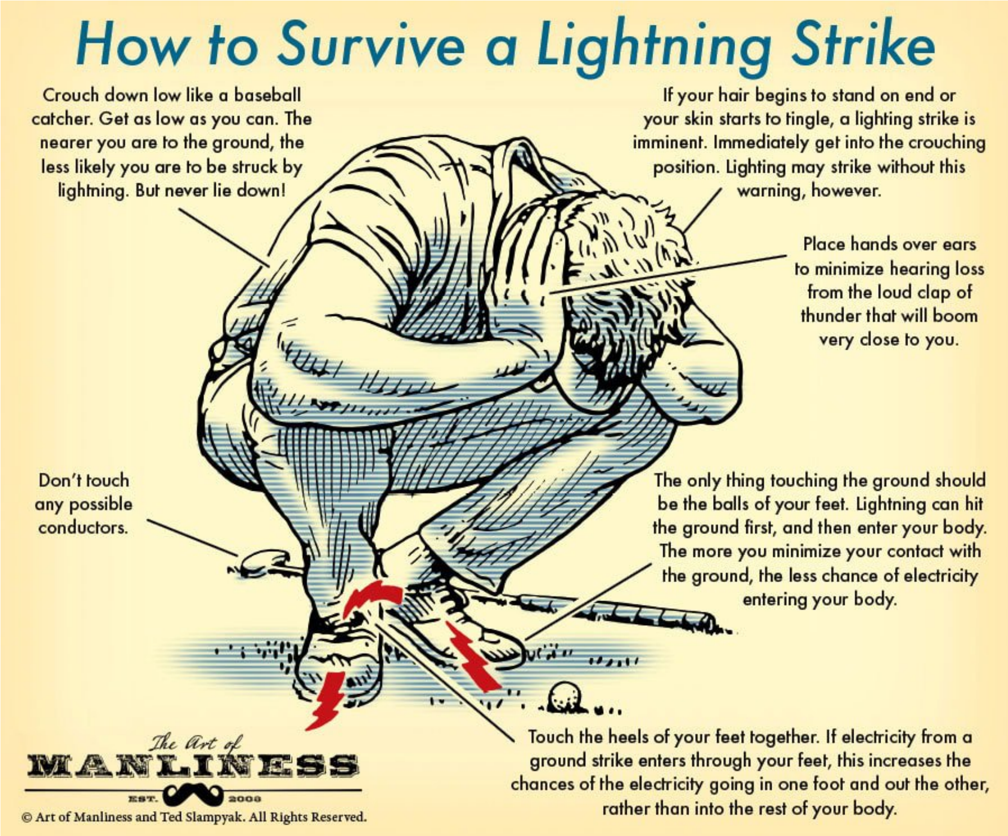
Students must not complete the experiments if they are epileptic, have a heart murmour or if they're a chicken.
NB Do not let the students push DOWN on the dome. This breaks the mechanism. The students only have to be lightly touching the VdG for it to conduct. It is not necessary for students to remove anything It is best for students to put their hands on the lower sides of the dome than on the top, this prevents the pressure on the belt. Providing contact is made with the VdG and the student is insulated then they should become charged.

The best hair for charging is fine dry hair. It doesn't work as well with greasy or thick hair. Demos are not usually very good on humid or damp days as the VdG discharges into the air.

It is usually best to complete this at the end of the lesson, as the students usually get quite excitable. If not have it at the very start and then move on to something else fun after a quiet time.

Firstly. DO NOT GO STRAIGHT ON TO GETTING THE STUDENTS HAIR TO RISE. The VdG must be explained. It is basically an improved version of rubbing rods on jumper. Charge moves up the belt (or down!) jumps off at the metal combs and collects around the outside. If you were inside you would have no charge on the inside. Charge collects on the outside only. This is why you are safe in a bird cage, car or steel boat during a thunderstorm.

https://www.youtube.com/watch?v=PdrqdW4Miao



- ◆¨ Then stick a piece of thread (very thin) with a small piece of blu-tak onto the VdG dome.
- ◆¨ Turn the VdG on and see how the thread rises up.
- ◆¨ Bring another piece of thread towards the VdG and see how it is attracted to the dome. Notice that it

  doesn't need to be touching the thread.

- ◆¨ A student can touch the VdG (discharge between each use)

  NB when the student is not insulated the current passes through the body and into the ground. It is not storing the charge.

- ◆¨ Then get the student to stand on a box (a deep old tray usually works well and can cope with approx. 11 stone if it is carefully spread)
- ◆¨ Repeat the process and now the hair ought to rise up. This is because similar charges are repelling and so to get as far away from each other the hairs rise and separate.
- ◆¨ Again bring a piece of thread close to the student and see how the electric field is quite far from the student. The electric field is the region where there is an electric force. Move the thread further away until it hangs down. This is then outside the field. As you move closer to the student the thread should rise more as the strength of the force and field is greater.
- ◆¨ Do not get too close to the student as you could discharge them and cause a spark
- ◆¨ Students should be moved at least 60cm from the student being charged and should not be moving

around the back to prevent discharge.

Lesson 4 -CONDUCTORS and INSULATORS

This is likely to be lesson 4 or 5. This could be completed prior to the static lessons as it is slightly different. It would then give students the chance to go through the structure of the atom before doing the static experiments which explain static.

Aims of LESSON 4- Conductors and Insulators

1. When electric charge moves we call it an electric current.
2. Current is a flow of charge (or electrons) around a circuit.
3. Materials that allow current through them are called electrical conductors.
4. Materials that do not allow current through them are called electrical insulators.
5. For electrons to flow there must be a complete circuit.
6. A multimeter can be set up to measure current, resistance or voltage.
7. When a multimeter is set up to measure current we call it an ammeter.

• **Hypothesising**

S • **Equipment Handling**

A L

• **Observing**
• **Design/construct/test/modify**

These experiments build up the idea of a circuit. It should introduce the idea that current needs a path for the electrons to take, which usually (but not always) returns to the start. Please note. Electrons don't all start at the cell but are in the whole circuit. This is shown well with marbles tightly in a line, Push anyone and they all move. It is sometimes good to start the current from somewhere other than the cell to remind students of this

Task 1- light a lamp

1. **Try to light a small lamp using the minimum amount of equipment. Draw what you did in your jotter.**
2. You ought to be able to use just 3 pieces of equipment. For example:

   i. a wire, lamp holder, lamp, batter battery holder etc.

ii. Each of these counts as one piece of equipment

3. If you use two wires, this counts as two pieces of equipment, a lamp holder or battery holder also counts as an extra piece of equipment.
4. **Draw a large diagram showing how you lit the lamp.**

NB the terminals of the lamp are on the bit at the bottom that sticks out and the sides. If both

were on the sides current would not pass into the filament! Please draw the students attention to the connectors for the lamp

5. NOTES: It is awkward having to cope with small fiddly equipment so we put the lamp and battery in holders.
6. Remake your circuit so that it is easier to use (ie add a lamp holder and cell holder, notice an additional lead is required).
7. Answer the following questions in your jotter.
   1. How many pieces of equipment does this use?
   2. Draw a diagram of your new circuit.
8. The circuit that you have just made can be used as a torch. It will also be used later to find out if materials allow current through them (are they conductors).
9. Can you improve it further (depending on the brightness of the lamp, you might want to use another cell) but also add a switch. This should be added so that the switch turns the lamp ON and not OFF

   You could introduce the idea of circuit symbols and why that is better than trying to draw the diagrams that you have been drawing. For example is this diagram anything like the circuits that the students were producing? Put up other diagrams of students with other kit. How would you tell if it was the same circuit? Therefore we introduce a new "language", that of circuit symbol. Issue as a homework exercise. Do not copy these out at school.

In which of the circuits would the lamp light?

10. Good conductors of electrical current allow electrons to flow through them easily. Sometimes they bump into atoms in the wire and this slows them down. This braking effect is called the wire's resistance.
11. The longer the wire, the more resistance it has.
12. A thin wire has a higher resistance than a thick wire.

    There is a smaller area of wire for the electrons to pass

    along.

13. **We will come back and look at resistance in more detail**

later.

Additional Notes (not required yet)

ELECTRIC CURRENT and conductors and insulators

When electric charge moves we have an electric current. Current will only flow if there is a complete path for it to follow. This is known as a circuit. You noticed this with the light lamp.

Wire

Battery

Bulb

It only lit if there was a complete circuit. Electric charge cannot flow through all materials. Current would not flow if one of these materials that electric charge cannot flow through was put in the circuit.
If a material, such as copper, lets electric charges move through it, we call it a conductor**.** An insulator does not let electric charges through, for example rubber. This is similar to the conductors and insulators of heat that you met in the first unit.

TEACHERS' NOTES & EXTENSION

Read and answer the questions on page 85 of Starting Science Book 1.

Collect six to ten marbles and line them up between two jotters so that they are touching each other. Push the marble closest to you. Record what you noticed.

Then answer the following questions.

1. Did all the marbles move?
2. Which marble moved first or did they all move together?

Now get your partner to put their finger at the end of the row. Now gently push the marble closest to you again. What happens?

1. How is this different from the last experiment?
2. How do you think this compares with charge trying to move in a conductor or insulator.

Get your teacher to go over this demonstration to show how it is similar to electricity and shows the difference between conductors and insulators.

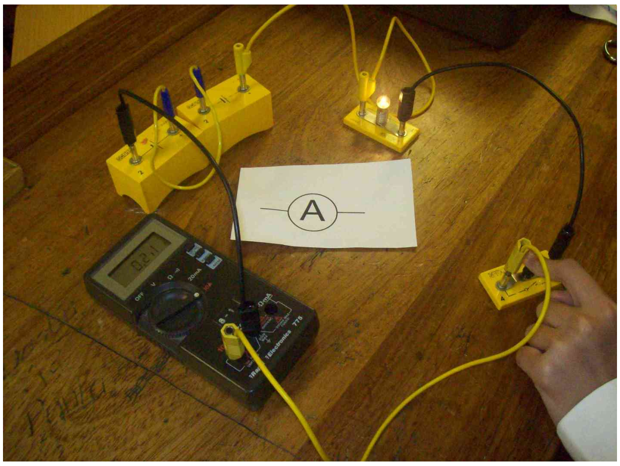
If pupils replace the switch with the material to test this is the correct circuit for experiment 1. Please use the YELLOW meters and connect up as shown in the other sheets ONE WIRE IN THE COM and ONE WIRE IN THE 10A. SWITCH THE DIAL to A WITH 2 STRAIGHT BARS not the other wiggly line above the A (this is for using on a.c.)

Testing materials for conduction and insulation

Building on from the torch circuit, which you could have introduced a switch if we have any (which we currently don't), you can introduce the idea of conductors and insulators.

You are going to complete TWO experiments to show which materials are conductors of electrical current and which materials are insulators of electrical current You already have a good idea of what types of materials you are looking for so try to test some unusual ones.

Write the heading in your jotter "Testing materials for Conduction of Electrical Current"



Draw a table out like the one shown. You will need a whole page for the table. You will use this table for two experiments. For the first experiment only fill in the first four columns.

METHOD

1. ***Set up the circuit like the one above.*** The first four columns are for Expt 1

1. Material 2. Prediction 3. Does the lamp light?

For Expt 2

4. Conductor or 5. Insulator? Current

(A)

6. Order (best conductor no 1 etc)

YOU MUST THINK SAFELY AND NOT TRY ANYTHING THAT COULD BE DANGEROUS. ASK YOUR TEACHER IF YOU ARE IN ANY DOUBT.
DO NOT PLACE ANY WIRES NEAR OR IN ANY ELECTRICAL SOCKET OR PIECE OF ELECTRICAL APPARATUS.

2. ***Choose a material to test.***
3. ***Record your material in column 1.***
4. ***Predict whether your material is a conductor or an insulator of electrical current.***
5. ***Fill in column 2.***
6. ***Carefully try out your material.***
7. ***Fill in columns 3 & 4 for your material.***
8. ***Repeat for other materials.***

9. ***You should be able to test at least 20 different objects or materials.***

Explain how the light lamp would tell you which objects were the best conductors of electrical current.

The experiment that you have just completed is not a very accurate way of measuring how much electrical current (electric current) is going round the circuit. The small light lamp that you used can be replaced with a meter which will measure how much current is flowing around the circuit (see the diagram below).

At this point you might want to introduce the meters and come back to this task later. Or order Ammeters only from the technicians. NB Ammeters go in series.

1. *Retest all your conductors and insulators using your meter.*
2. *Fill in the fifth column in the table.*
3. *From your current readings try to list your objects in order, starting with the best conductor at the*

top.

The circuit that you built to test whether something was a conductor or an insulator is called a continuity tester.
Not all conductors are equally good at letting charge through. Some resist the current more than others. We say these materials have a high resistance

The meter is called a multimeter and it can be set up to measure current, resistance or voltage. When it is set up to measure current we call it an ammeter.
An ammeter is used to measure current.

LESSON 5,6: METERS

This lesson can be done very quickly or you can give the students a chance to use their skills in which case this will take 2 periods.. Go through with the students how each meter is connected. The COM is the common terminal so the negative lead (one closest to the negative terminal always goes in here). Students should be issued with a cut out of the types of meter and the table. This should be 2 students material to 1 A4 page. If you don't feel confident with multimeters use individual Ammeters and voltmeters, but students are unlikely to meet these anywhere else in their life, so I believe in training them young. Feel free to disagree.

When dealing with "the topic of electricity" it is sometimes helpful to be able to use a meter to measure current, resistance and voltage. For example, if you muddled up old and new batteries how do you sort them out? Using a voltmeter will distinguish between the old and the new. An ohmmeter can tell you if there is a break in the circuit. An ammeter will show you if you are overloading a circuit.

Rather than using a separate meter to measure each of the quantities, it is easier to buy a meter that can be adapted to take

readings of different quantities. Such a meter is called a can be very useful

Aims of Lesson 5 & 6 Meters.

1. We use the symbol I to mean current.
2. Current is measured in amperes or amps.

They are fairly cheap to buy and with careful setting up

ammeter.

3. Current is measured using an
4. The symbol for an ammeter is

A

5. A multimeter can be set up to measure current, resistance or voltage.
6. When a multimeter is set up to measure current we call it an ammeter.
7. Some materials have a high resistance and make it difficult for current to flow.

8. A continuity tester can be used to test for conductors and insulators.
9. Resistance is a measure of how difficult it is for the charges to move through an object.
10. The longer a wire the higher the resistance of the wire.
11. Voltage is measured in volts.
12. Voltage is measured using a voltmeter, symbol V,_.
13. Voltmeters are connected in parallel.

S •

- **Equipment Handling**
- **Observing**
- **Design/construct/test/modify**
- **Line graphs**
- **Taking Readings**

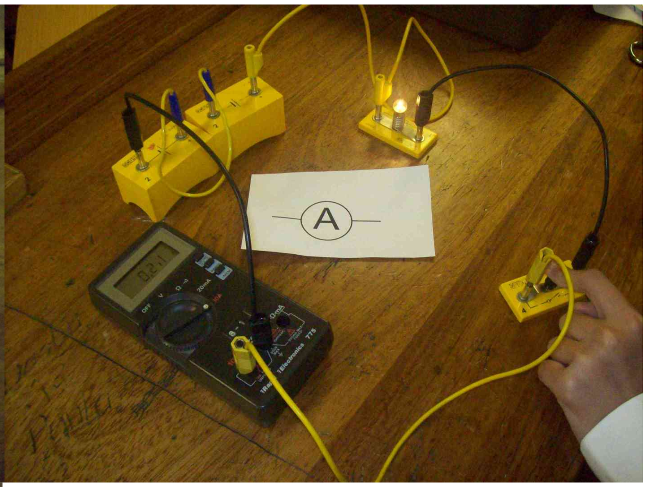
Examples of multimeters are given below.

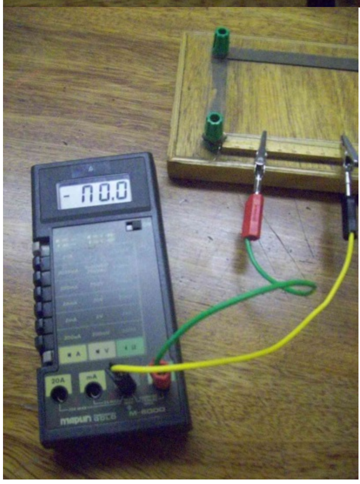
MULTIMETER.

V

A L

Measuring





The symbols for each meter are given below.

Meter symbol

Meter

Ammeter

Ohmmeter

Voltmeter

IMPORTANT INFORMATION ON CONNECTING Ammeters are used to measure the current in a circuit.

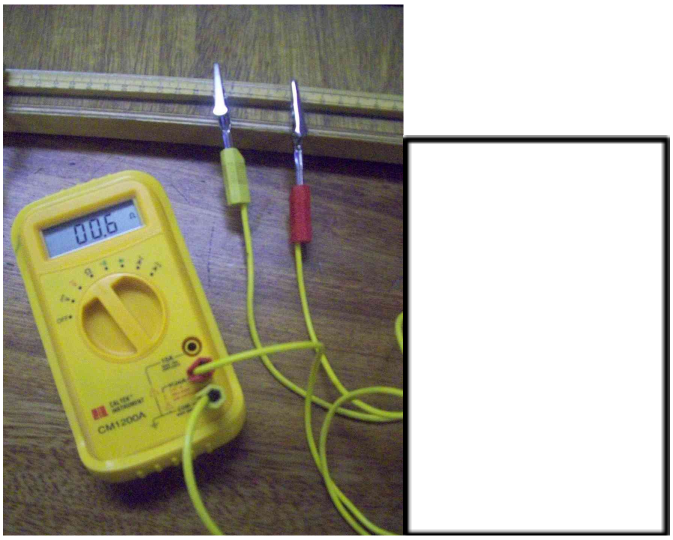
The wires connect to the COM (negative) and 10A (positive). Only if the current is small can you connect it on the mA scale, but beware, too much current and the fuse will blow and the meter wont work. AMMETERS are connected IN SERIES

Ohmmeters are used to measure the resistance of a component or a circuit. The wires connect to the COM (negative) and W *(positive). OHMMETERS must not be used with a power supply*

Voltmeters are used to measure the voltage in a circuit.
The wires connect to the COM (negative) and V (positive). VOLTMETERS are connected in PARALLEL across the component.

Connecting An OHMMETER to measure resistance

Notice there is no power supply and no other component, just what you want to test. Just add two wires to your meter and place it across your test component. Connect one wire into the COM terminal of your meter and the other to the W/V. Turn the dial to the W symbol.



W

V/W

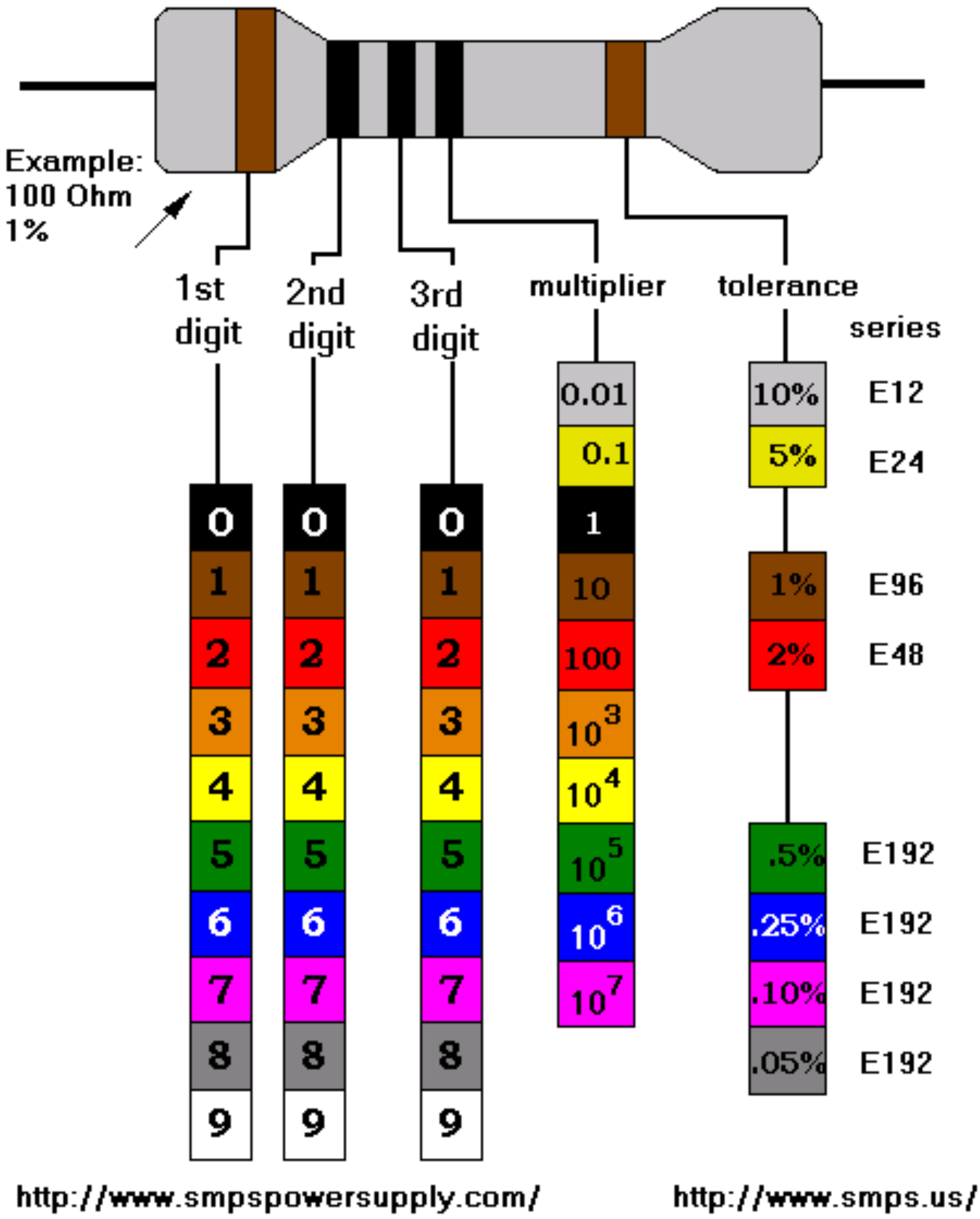
com

10A

Test material

Some Resistors that we use in School are very big and their real purpose is to help students understand how they work. In everyday appliances the resistor is found in the majority of electrical circuits and the length of the resistances is very small. Here is a diagram showing the code to work out the resistance of resistors.

Go through the use of meters with the students, make sure they have diagrams of the connections to be made when using a multimeter. If you wish you can use the ammeters and separate voltmeters but these are generally in everyday use.



Measure + Record. TASK

Each group needs to complete at least 2 of the following tasks

1. *Voltage across a Cell. Measure the voltage across the 1.5V cells, are there any that are "flat" or have used the energy they contained*
2. *Currentinthecircuitof1cell,1lamp*

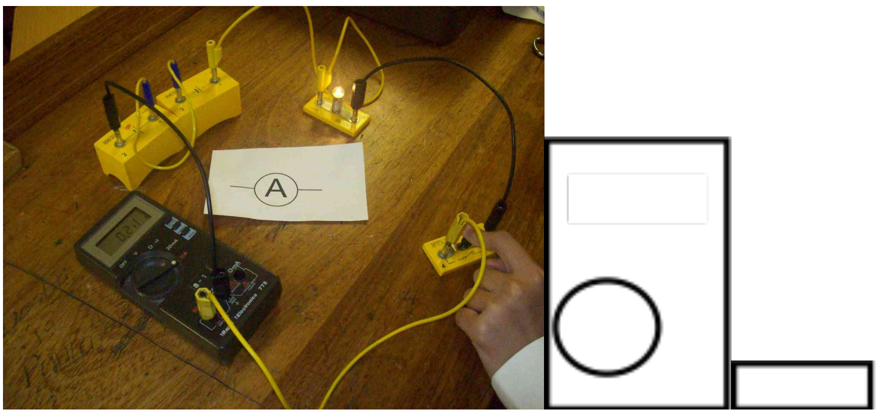
3. *Resistanceofeachobjectinthepots*
4. ***Resistanceofawireoflength10cm,20cm,30cm,40cm,50cm,60cmetcNBThi sisa great task to introduce graph, averages and repeated measurements. This is a very repeatable experiment and you should get almost identical results each time. This gives great opportunities to plot graphs using excel or paper method. A good line of fit is achievable.***
5. Return to the experiment completed last lesson with the adapted torch ciruit which is being used as a Continuity Tester Test the current in the circuit where Current in the circuit when each item in pot is placed in the c
6. *Comparingquotedresistanceandmeasuredresistance.Take4or5resistorswit h different markings.*
    1. *Recordthecolourmarkingsontheresistors.*
    2. *Workoutfromthediagramtheexpectedresistanceofeachresistor.*
    3. *Nowuseanohmmeterandcheckwhetheryouarecorrect.*
    4. *Explainwhytherecouldbedifferencesbetweenwhatyouexpectasanan swer and the value you obtain.*

Teacher notes, you can allow all students time to produce a graph of length against resistance or you can introduce excel to the students or this can be given to the those who complete the task as a homework exercise. This can form one of the SALs though

Connecting An AMMETER to measure current

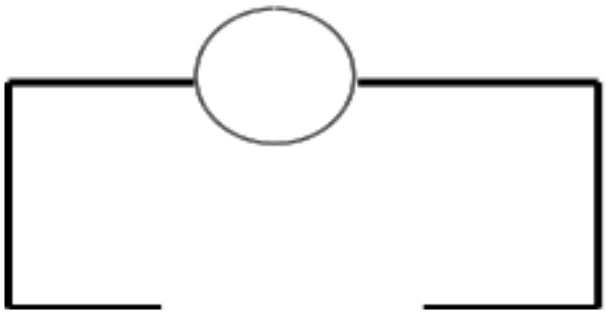
An Ammeter must have a load (component) and power supply to make it work. Connect one wire to the COM terminal and one to the A symbol. If the current is very small then the second wire can be connected to the mA terminal but if the current is too large and you connect to this terminal you will blow the fuse inside and it will not work. Turn the dial to the A symbol (this should have straight lines above it not wavy which is used for a.c)

The lamp is not necessary but it shows you quickly if you are getting current in your circuit.

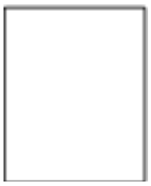


A
1

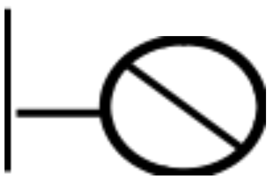
V co



A

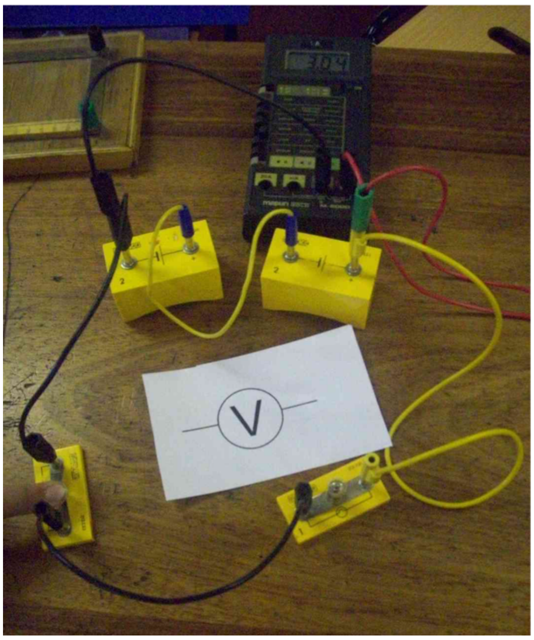


TEST
MATERIAL



Connecting A VOLTMETER and measuring voltage

A Voltmeter must be placed ACROSS a component in a circuit. Voltmeters always go in parallel. Connect one wire to the COM terminal and one to the W/V symbol. The easiest way is to build your test circuit and then connect the Voltmeter across the terminals where you thing the circuit is not functioning or where you wish to measure the voltage. It is probably the easiest meter to use. If you want to see if one of your cells is near the end of its working



life then connect a voltmeter staright across the terminals (top and bottom) and it will give you the voltage. Usually most cells are rated at 1.5V. A new cell could give you a reading of 1.65V but some devices will no longer function if the cell voltage drops below 1.3V.

LESSON 7: Learning Terms

Aims of Lesson 7 Learning Terms

- **Literacy Task**

S A

L

1. We use the symbol I to mean current.
2. Current is measured in amperes or amps.
3. Current is measured using an ammeter.
4. Ammeters are connected in series.
5. The symbol for an ammeter is
6. For electrons to flow there must be a complete circuit.
7. A multimeter can be set up to measure current, resistance or voltage.
8. When a multimeter is set up to measure current we call it an ammeter.

Resistance

9. Some materials have a high resistance and make it difficult for current to flow.
10. A continuity tester can be used to test for conductors and insulators.

11. Resistance is a measure of how difficult it is for the charges to move through an object.
12. The longer a wire the higher the resistance of the wire.

Voltage.

13. For most materials, as you increase the voltage the current increases. 14. Potential difference (p.d.) is often called voltage.
15. p.d. is the push that makes the charges move around a circuit.
16. Voltage is measured in volts.

17. Voltage is measured using a voltmeter, symbol V,_. 18. Voltmeters are connected in parallel.

V

We can't get around it there are some terms that are associated with electrical current that the students are required to know. I have found a fairly successful method of learning these is to complete this group reading task! There are laminated boards with the terms. NB it is much harder to add the meanings to a board of terms than the terms to a board of meanings, so use this as a method for differentiation. There are various sheets that students can use at the end, either copying these into their jotters, or being given the word and write the meaning, meaning and write the word or a completed table. This is the one long written task I do over the whole block, the rest is written at home.

NB there is no definition of charge in the text but it is the one definition they ought to have not covered at the end of the task. This then indicates which is correct. Some of the boards have numbers and letters on them. If you read across from right to left then the numbers and letters go in order. Some students work this out for themselves.

Definitions

I play this as a "BUZZ" game. Students call out BUZZ after I mention a definition given in the text. Students then repeat the meaning and the word and place the word on the board. If you find a more successful method let me know. There is an activinspire board that has the definitions and terms produced by Stuart Bell. **PLEASE don't save this Activinspire with the completed answers unless you keep your**

A

own version. It will be awkward for the next person if the answers are already given. I find this Activinspire works well as a revision tool the next lesson to check who has learned the terms. I will get the words onto the website or GLOW for students to

download

Using the words below write a report or your own dictionary to explain their meaning

a) *Current* b) d) *Resistance* e) g) *Ohmmeter* h) j) *Insulator* k) m) *Series circuit* n) *p) The effects of a current*

Charge
Ammeter Multimeter Potential Difference Parallel circuit

c) *Voltage*
f) *Voltmeter*
i) *Conductor*
l) *Circuit*
o) *continuity tester*

1. *Electric charge is produced from the outer parts of atoms called electrons. When these small charges or electrons move around a circuit we call this a current, electric current or electrical current. When an electric current passes through a conductor it produces several useful effects, heat, light, magnetism, and chemical effects.*
2. *You will only get an electric current if there is a complete path for it to follow. This is known as a circuit. For example a light lamp will only light if there is a complete path from the power supply through the lamp and back to the power supply. We use the symbol I to represent current so we don't have to write out the whole word. I was used as people used to refer to current as intensity. The unit of current is the ampere or amp. Current is measured using an ammeter.*

   Ammeters are connected in series. The symbol for an ammeter is

3. *Electric charge cannot flow through all materials. Materials that charges flow through easily, such as copper, are called conductors. Materials that charges cannot flow through, for example rubber, are called insulators. These materials are similar to conductors and insulators of heat. Notice, materials that are good conductors of heat are also good conductors of electrical current, and materials that are bad conductors of heat are also bad conductors (or good insulators) of electrical current.*
4. *The number of free electrons in a substance determines how well it conducts electrical current. Metals such as aluminium, copper, silver and gold are good conductors because they have at least one free electron per atom. Some metals, such as lead and tin, are poorer conductors than other metals because they have less than one free electron per atom. Substances with no free electrons, such as glass, and rubber, do not normally conduct electrical current. They are called insulators.*
5. *Resistance is a measure of how difficult it is for these charges to move through an object. Poor conductors resist the flow of electrical current more than good conductors. Resistance changes electrical energy into heat. Not all conductors are equally good at letting charge through. Some resist the current more than others. We say these materials have a high resistance. Resistance is represented by the symbol R and is measured in units called Ohms (symbol W) Resistance is measured with an Ohmmeter which has the symbol*
6. *The electrical push that allows charge to flow is called voltage. It is also a measure of the energy given to each of the charges as it passes through the power supply.*
7. *Potential difference (p.d.) is often called voltage. p.d. is the push that makes the charges move around a circuit. Voltage is measured in volts. Voltage is measured using a voltmeter. Voltmeters are connected in parallel and have the symbol*

8. A circuit that can be built to test whether something was a conductor or an insulator is called a continuity tester.

than using a separate meter to measure current and voltage and resistance

This meter is called a multimeter.

9. Soon we are going to find out that there are two types of circuit that we can build. Remember that . Charge flows through all the components.

. An example of each is given below.

A

A series circuit

Rather

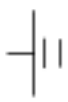
one meter can be used on different settings.

in a series circuit

there is only one path for the current to take

In a parallel circuit there is more

than one path for the current to take



A

The lamps are in parallel

Lesson 8: S2 APPRENTICESHIP ASSESSMENT BUILDING CIRCUITS LESSON

Aims for Lesson 8- Building Circuits

By this time students should have drawn the circuit symbols and so ought to know the familiar symbols they will be using.
The purpose of today's lesson is

• to draw circuits using symbols
to build circuits from a description
to build circuits from a diagram
to distinguish between different circuits

Circuit symbols are used to show how circuits can be built.
The circuit symbol for a cell, switch, bell, ammeter, voltmeter, lamp, power supply, resistor, wire, connected wire.
Make sure that you can draw circuits using the proper symbols and following the rules for drawing circuits.
The two types of circuit are called series and parallel.

• equipment handling • Observing
• Diagram
• Problem solving

Design/ construct/ test and modify

To complete all the circuits will take most students between 1.2 and 2 lessons, there will always be a group of students who have difficulty with their equipment. These are generally the most scared students! Sometimes it is best for the students to put all the kit back and start again, or swap it with the group that are storming ahead!

INTRO TO LESSON: FAULT FINDING (1)

If possible try to introduce this at the end of the last lesson so it will give you a chance to do the building circuits lesson in one or 1.5 lessons. Do not take longer than this to complete the task or the students will get frustrated. If they finish I will make up some additional work sheets, or use the old electricity notes and they can build some of the circuits given after paragraph 125. This can also be completed or introduced when doing the torch circuit and conductors and insulators. There are fault finding laminated cards in the filing cabinet, please collect all 20 up at the end of the lesson.

INFORMATION
You may often find that circuits do not always work when you connect them up. There are a

few useful things that you can do before you panic and call in the teacher.
CHECK THAT:-

1. the batteries are all connected up the right way,
2. the wires are all connected up and make a complete circuit,
3. the batteries are not flat,
4. the lamp has not blown,
5. the lamp holder is not broken,
6. your meter is connected properly and that the right buttons are pushed in (there should be a poster on

   the wall to show you),

7. the equipment is plugged in and is switched on,

8. Check that you have checked everything.

If you have checked all that could have gone wrong and your circuit still doesn't work now panic and call in the teacher!
PLEASE NOTE THIS TASK IS ABOUT STUDENTS FINDING OUT ABOUT SERIES AND PARALLEL FOR THEMSELVES. Students ought to have completed this at primary school but if 1 in 20 can do this I'd be surprised. There is always one group with kit that doesn't work. So it is a good idea to give each group a Fault Finding card. Have plenty of spare kit. Generally the cells are flat or connected the wrong way around. You are more likely to get this to work if you use 1.5V lamps but they can be easily damaged. So beware!

We are asking a lot of students this period and it is exhausting for the teacher, but the students and teacher gets so much out of it. It is about students seeing their improvement. PLEASE CHECK STUDENT DIAGRAMS, ESPECIALLY THE FIRST FEW, BEFORE ALLOWING THEM TO MOVE ON TO THE NEXT CIRCUIT. Generally the students put symbols in the corners, are unable to turn a switch upside down and make their cells look like a capacitor. Alex Fuhrmann came up with an excellent idea to use a quiz board underneath the circuit so they can use the quiz board to help draw out the circuit. NB THIS TASK MUST BE COMPLETED AFTER STUDENTS HAVE DRAWN OUT THE CIRCUIT SYMBOLS.

The purpose of today's lesson is
- to draw circuits using symbols

- to build circuits from a description
- to build circuits from a diagram
- to distinguish between different circuits

TO DO
Come in get out your jotters.
Check that you have copied all the necessary circuit symbols. If not sit in the corner and copy these ALL out from the sheets Collect the following apparatus

- 7 x leads
- 2 x 1.5V cells & holders ◆ 3 x 2.5V lamps & holders ◆ 2 x switches

Wait silently for instructions.
Complete the circuit for the activity. For each circuit you must read the description and build the circuit correctly

Summary

We built 7 circuits. A circuit is a complete PATH. There are 2 types of circuit. In a series circuit when one lamp is unscrewed the others go off. In a parallel circuit when one is unscrewed the other stays on.
In a series circuit there is only ONE path for the current. In a parallel circuit there is MORE THAN ONE path.

LESSON 9: MODELLING ELECTRICAL CURRENT

Aims of Lesson 9 Modelling

1. In series circuits the current is the same all round the circuit.
2. In parallel circuits the current splits up and some goes down each branch.
3. In series circuits the voltage across the components adds up to give the voltage of the supply.
4. In parallel circuits the voltage is the same across each branch.
5. The current drawn from the supply increases the more components are connected in parallel.
6. When lamps are added in parallel the current drawn from the supply increases. This is because the

overall resistance of the circuit is reduced.

• Hypothesising • Processing

The electricity topic is a difficult concept for students and so it can be a good idea to model the topic of electricity and I find this model works really well. Students are able to predict the rules for current and voltage for series and parallel from this model.
I have had a board made once and it might be something we might want to consider redoing, using smarties as the energy source. Alternatively a large sheet of flip chart paper on the table works well and it can be quite interactive. Students can play the role of ammeter, lorry driver/ electrons/ battery- factory owner etc. This is often more difficult for the more able students who are not aas keen or do not feel that they need the model. This might be a place for the most able students to complete the Ohm’s Law practical.

Students should draw their own models in the jotters as you go along.
It can take 2 periods to do the model thoroughly, but the result is that they can complete the measuring current and voltage in series and parallel much quicker, under a period.
If you want the run down let me know. I’ll train the technician and he can decide if we want to remake the model (my DIL had produced a board from a wall paper pasting table with the road signs fixed in and egg box individual egg slots as the lorries. We might be able to buy ready made signs from children toys.

A town called CIRCUIT

TESCO

Model

Factory

Lorry

Shops

Road

One way street

Counting cars

(in the street)

In a series circuit the counters all count the same number of lorries

No. of boxes of mars bars=voltage

Weighbridge (see place at Carlisle)

PARALLEL

The boxes of mars bars in our series circuit adds up to what is delivered to each shop

The boxes of mars bars in our series circuit adds up to what is delivered to each shop

In a 2 branch town the number of mars bars each lorry delivers is the same as the total

The topic of electricity Battery
Electrons
Light lamps

Wires
Current goes one way
Ammeters
(go in series)
In a series circuit current stays the same.

Voltage is the ENERGY per CHARGE Voltmeter GOES IN PARALLEL

In a series circuit the voltage across each lamp adds up to the total.

In a series circuit the voltage across each lamp adds up to the total.

IN a parallel circuit the voltage across each branch is the same as the supply.

IN CIRCUIT TO AVOID CONGESTION ALL ROADS ARE ONE WAY!
This means all electrons flow in one direction only.
Circuit was built to provide a route from the factory.
The factory is the cells or battery or power supply and this pushes electrons around the circuit.
No factory no lorries.

Voltage is BOXES OF MARS BARS PER LORRY.
Measure the voltage by "sampling a very small number of charges" Voltmeters must go in PARALLEL. This is like the Weighbridge at Carlisle. Some lorries are taken off and the cargo of mars bars checked. Shops are equal to component eg lamps, resistors, motors, buzzers.
The factory produces MARS BARS
Mars bars give us ENERGY.
Cells produce energy
If we made the factory bigger it could produce more mars bars, more energy, need more lorries.
The more cells the more energy is produced and the higher the current.
Lorries take the mars bars to the shops.
Electrons or charge take energy to the components.
People count lorries at the side of the road.
Ammeters count the charge flowing each second in the circuit. Ammeters go in series.
In our town of circuit when the shops come one after the other, all the people count the same number of lorries.
In a series circuit the current stays the same.

$I_t=I_1=I_2=I_3$

This is like the power supply. The power supply pushes the charges around the circuit. They provide the

energy to the charges. The energy per charge is the voltage.

When counting trucks you stand at the side of the road. When checking mars bars per truck you need to pull off some trucks.
Ammeters go in series, Voltmeters go in parallel.
Mars bars are energy-

Voltage is the energy supplied to each charge or electron
Voltage is also known as potential difference. This is like the difference between the energy each charge has before the component compared to after. (how many boxes of mars bars have been dropped off!)

In our town, the number of boxes of mars bars delivered to each shop adds up to the total on the truck at the factory.
In series the voltage across each lamp adds up to the total from the supply.

$V_s=V_1+V_2+V_3$
In parallel in our town, the number of trucks in each branch adds up to the total.

In parallel circuit, the current in each branch adds up to the total.

$I_t=I_1+I_2+I_3$
In our town in parallel each truck delivers the same number of boxes of mars bars as was given at the

factory.

In parallel the voltage across each branch is the same as the supply.

$V_s=V_1=V_2=V_3$

Model
Road
Trucks
Traffic
Factory
Mars Bars
Counting lorries (at side of the road)
Lay-by with weighbridge counting mars bars per lorry

Road
One way
Factory extension, would mean more lorries on the road and more mars bars per lorry

What it means wires
charge
current

Cells, power supply, battery energy
Ammeters (go in series) Voltmeter (go in parallel)

Wires/ circuit
All electrons flow in one direction only
Bigger power supply
More energy per charge, bigger current and higher voltage
Parallel circuit

Two street town
NB this is not the completed model and I will add to it as I remember.

LESSON 10: MEASURUNBG CURRENT AND VOLTAGE

Aims for Lesson 10 Measuring current and Voltage

1. In series circuits the current is the same all round the circuit.
2. In parallel circuits the current splits up and some goes down each branch.
3. In series circuits the voltage across the components adds up to give the voltage of the supply.
4. In parallel circuits the voltage is the same across each branch.
5. The current drawn from the supply increases the more components are connected in parallel.
6. When lamps are added in parallel the current drawn from the supply increases. This is because the

overall resistance of the circuit is reduced.

•

- **Hypothesising**
- **Planning**
- **Measuring**
- **Observing**
- **Processing data**

• Diagram
• Problem solving • Design/ construct/

test and modify

equipment handling

If you've already gone through the model this can be completed very quickly. If the students have rushed through in other areas here is a chance to take time and carefully allow students to become confident with the apparatus. Measuring current in parallel is the most difficult to set up. I will see if we can get some boards makde up so that meters or wires can just be plugged in, although this is not giving students the skills to do this for themselves. You may wish to allocate groups to each of the 4 measuring tasks and then students can move around collecting results from each group. This works well and give the ASN students voltage in series to set up, as it is by far the easiest. You are likely to find that the voltage values do not remain constant in the parallel circuit as they should and students will talk about it being further to get to the bottom branches, which is mince, so please go through this. The real reason will be poor connections and therefore losses elsewhere that aren't measured. Also please ensure students don't get the idea that the current "runs out" by the time it has got around a series circuit!

MEASURING CURRENT IN A SERIES CIRCUIT

Position
I_t 0.135

1. I_1 0.135
2. I_2 0.135
3. I_3 0.135
4. I_4 0.135

Conclusion:
In a series circuit the current stays the same. There is only 1 path for the current so all

electrons flow along this path.

MEASURING CURRENT IN A PARALLEL CIRCUIT

Current (A)

I_4 I_t

I_3 I_2 I_1

Position

I_t
I_1
I_2
I_3
I_4 (I_1+I_2)

I_5

Current (A)

0.57 0.19 0.18 0.20 0.38

0.58

I_t

I_1 I_2

I_3

I_5

I_4

V_1 V_2 V_3

Conclusion In a PARALLEL circuit the current splits up and flows down different branches. The current in the branches adds up to the total current in te circuit which passes through the cells.

MEASURING VOLTAGE IN A SERIES CIRCUIT

Position

V_s

V_1 V_2 V_3

VOLTAGE (V)

2.8

0.878 1.095 0.881

V_t

Conclusion
In a series circuit the voltages across the components (lamps) adds up to the supply voltage (V_s)
REMEMBER VOLTMETERS ARE CONNECTED IN PARALLEL, AMMETERS ARE CONNECTED IN SERIES

MEASURING VOLTAGE IN A PARALLEL CIRCUIT

VOLTAGE (V)

V_s 2.30 V_1 2.26

V_2 2.26 V_3 2.30

the same.

V_t

V_1

Position

In a voltage

Conclusion. parallel circuit the

V_2 in each branch remains **FAULTS**

V_3

(MUST BE COMPLETED AFTER METERS best COMPLETED AFTER THE SERIES AND PARALLEL WORK), could be before measuring current and voltage in series and parallel if you're short of kit
This is a tiring lesson that the students find great fun. It is best completed when there is technical support around as the students often fix the boards and you can't remember what was wrong with them or they create a new fault.

IF YOU ARE WORRIED OR HAVE A POOR CLASS IT MIGHT BE ADVISEABLE TO SWITCH OFF THE ELECTRICITY AT THE RCD, if you know where the key is to put it back. I will provide a list of faults and why they occur, but as they are ever changing it might not be reasonable in here.
PLEASE ISSUE

LESSON 10: TESTING FOR

Aims for Lesson 10- Testing for Faults

- **equipment handling**
- **Observing**
- **Problem solving**
- **Design/ construct/ test and modify**

Resistance –

Resistance is very low
Resistance depends on the size of the resistor. It can be **low high**.
Resistance is very very very high

a measure of "how hard it is for electric current to flow" With a **large** resistance – "**hard**" for current to flow With a **small** resistance – "**easy**" for current to flow

If there is a break in the circuit, there would be a very, very high resistance. (OPEN CIRCUIT)
If there was a wire across a component, the resistance across the component would be very low (SHORT CIRCUIT)4

Short circuit Open circuit

~ 0.00l

W

W
com W

l.

MW

com W

Reads a very low number

W

Reads a very high number

Circuit being tested

Test continuity with an ohmmeter.
Remember the power supply must be off or disconnected before using it.
If the lamp is ok, then the ohmmeter will give a small reading. However, if the lamp is “blown” then it will be an open-circuit and there will be a very, very large reading on the ohmmeter.

W

Make a continuity tester with an ohmmeter and lamp.

Circuit being tested

A

When connected to the lamp on the right, if there is an open circuit, no current would flow, therefore, 0.00A on ammeter.

A

Test with a lamp. The lamp would be bright to indicate a short circuit and off to indicate an open circuit.

TASK

Around the room are circuits that are not working. OR if your teacher says it is safe set up a circuit that will not work for another group. **ELECTRICAL HAZARD. NO EQUIPMENT FROM TODAY MUST BE INSERTED INTO THE SOCKETS. IF IN DOUBT TURN OFF YOUR ELECTRICAL SUPPLY** Your task is to identify what is wrong with the circuit. Try to fix the circuit by following the checklist. MAKE SURE THAT YOU PUT THE CIRCUIT BACK AS YOU FOUND IT AFTER YOU HAVE FOUND OUT WHY IT DOES NOT WORK.

Did you find the following faults?

1. cells connected the wrong way (beware that these will go flat unless they have a switch)
2. flat battery
3. a wire across the lamp, thus shorting out the lamp
4. a blown lamp
5. a broken wire

Below is a circuit of a lamp and a battery being using as a continuity tester. (This is the circuit that was used in second year.)

Circuit being

tested

6. a wire connected without the insulation removed.
7. a fuse in the circuit which is too low powered and blown
8. a lamp holder wrongly wired so the wires are shorting out the lamp
9. a blown lamp in a series circuit
10. a blown lamp in a parallel circuit
11. the circuit is incomplete.

LESSON 12: Fruit Batteries

Aims of Lesson 12- Fruit Batteries

1. I can help to design simple chemical cells and use them to investigate the factors which affect the voltage produced.

- **equipment handling**
- **Planning**
- **measuring**

Additional Learning Outcomes (extension)

- **Observing**
- **Diagram**
- **Problem solving**
- **Design/ construct/ test and modify**

2. Using experimental evidence, I can place metals in an electrochemical series and can use this information to make predictions about their use in chemical cells. SCN 4-10a
3. Using a variety of sources, I have explored the latest developments in chemical cells technology and can evaluate their impact on society. SCN 4-10b

By Jerry Loomer http://www.usc.edu/org/edisonchallenge/2008/ws1/FruitBatteries.pdf
A battery is an electronic device that **changes chemical energy into electrical energy**. The chemical

energy is sort of like the energy in the food we eat. When we want to run or jump, our bodies change the food (chemical energy) into motion (kinetic energy). Similarly, the chemicals in a battery are storing energy that can be released as a flow of electrons (electric energy).

Batteries need three parts.

1. **1) A cathode (negative electrode), and**
2. **2) anode (positive electrode), and**
3. 3) **an electrolyte (material to push the electrons)**.

When making a fruit battery, the juiciness of the fruit or vegetable is the electrolyte, and the two metals inserted into the fruit are the electrodes. Which is the cathode and which is the anode depends on what pair of materials you are using.

Materials

- Fruits or vegetables: lemon, orange, apple, kiwi, grapefruit, potato, sweet potato, onion.

- Metals: copper (penny), nickel (nickel), iron (regular nail), zinc (galvanized nail), aluminum, tin (solder), carbon (mechanical pencil lead), wood (dowel), plastic
- Paper Towels
- Multimeter

Purpose:

• The purpose of this experiment is to determine the electrical voltage output of different combinations

of electrodes and fruits.
It will also find out:-
• which fruits give the highest voltage outputs.

- if the separation of the electrodes affects the voltage output.
- the voltage across different pairs of electrode materials.
- And examine the voltage outputs when the electrodes are connected in series and in parallel.
- the current produced by different pairs of electrodes.
- and examine whether the depth the electrode is inserted into the fruit affects either the voltage or

amperage outputs.

Procedure:

1. 1) Roll the fruit a little to make it a little juicier in the inside.
2. 2) Insert one electrode material into the juicy part of the fruit.
3. 3) Insert a second electrode into the juicy part of the fruit, but not so the two electrodes touch.
4. 4) Measure the voltage across each pair of electrodes as explained below.
5. 5) Place the ammeter in series and measure the current as explained below. You may require a small

   resistor to produce a load.

6. 6) As you collect data, be sure to identify the fruit, the cathode material, the anode material, and the voltage

   that it reads so you can identify which experiment you were conducting.

7. 7) As in all scientific work, only change one variable at a time. By keeping all of the other variables

   constant, you will be able to see if the one that you are changing is causing the effect. If you vary two or more between trials (different electrodes placed at different separations in different fruits and inserted down to different depths), the different voltage or current values that you get can't be tied directly to any particular variable.

Voltage measurements:

- Set the Multimeter so that it is measuring DCV (Direct Current Voltages).
- The 200mV setting will give voltage readings up to 2.000 volts. If the readings are too high or too

  low, just change the dial setting.

- It may be hard to maintain a solid contact with the pointed multimeter probes, it might be better if

  you use a pair of alligator clip leads and attach one side to the end of the pointed probe and clip the other end of the lead to the electrode. If you get a negative voltage reading, reverse the clips on the electrodes. The red lead goes to the anode of the fruit battery and the black lead goes to the cathode.

  Current measurements:

• When making current measurements turn the dial on the Multimeter to and set the dial at the range

setting most appropriate for the range of current readings you are experiencing. The 200 μA is the most sensitive, which means that it will record the smallest currents while the 200 m is the range for the largest currents. (Some multimeters adjust themselves automatically) You may need to use a digital meter.

Analysis:
A line graph should be drawn if both sets of data are numerical values (ie. separation, depth) and the results (ie. Voltage or current) to show how the values change.
When the variable quantity is not a numerical value (ie. Type of fruit, type of anode), bar graphs of your results should be drawn.

Fruit Batteries Data Sheets

Question 1: Does the distance between the electrodes affect the voltage?

Measure the voltage as you change the distance between the electrodes. Be sure the electrodes are inserted parallel to each other and that they are inserted the same distance into the fruit each time. Use only one type of fruit.

Fruit
Cathode
Anode Separation (cm) Voltage (V)

1.0 2.0 3.0 4.0

Question 2: Does the distance between the electrodes affect the amperage?

Measure the current (mA) as you change the distance between the electrodes. Be sure the electrodes are inserted parallel to each other and that they are inserted the same distance into the fruit each time. Use only one type of fruit.

Fruit
Cathode
Anode Separation (cm) Current (mA)

1.0 2.0 3.0 4.0

Question 3: Does the type of fruit affect the voltage?

Measure the voltage as you change the type of fruit. Be sure the electrodes are inserted parallel to each other, that they are always the same distance apart, and that they are inserted the same distance each time.

Cathode
Anode Separation (cm) Fruit

Voltage (V)

Question 4: Does the type of fruit affect the current?

Measure the current (mA) as you change the type of fruit. Be sure the electrodes are inserted parallel to each other, that they are always the same distance apart, and that they are inserted the same distance each time.

Cathode
Anode Separation (cm) Fruit

Current (mA)

Question 5: Does the type of anode (-) affect the voltage?

Measure the voltage as you change the anode. Be sure the anodes are inserted parallel to the cathode and that they are inserted the same distance into the fruit each time. Use only one type of fruit. Use only one type of cathode although the experiment can be repeated with different cathodes and checked against the different types of anode materials.

Fruit
Cathode Separation (cm) Anode
Voltage (V)

Question 6: Does the type of anode (-) affect the current?

Measure the current (mA) as you change the anode. Be sure the anodes are inserted parallel to the cathode and that they are inserted the same distance into the fruit each time. Use only one type of fruit. Use only one type of cathode although the experiment can be repeated with different cathodes and checked against the different types of anode materials.

Fruit
Cathode Separation (cm) Anode
Current (mA)

Other Questions:

- Does the insertion depth of the electrodes affect the voltage and/or current?
- Does the angle of insertion of the electrodes affect the voltage and/or current?
- How does having the electrodes touch above (or inside) the fruit affect the voltage

  and/or current?

- Using a crocodile clip leads, make a series set of fruit cells and see what maximum

  voltage you can get.

- Using crocodile clip leads, make a parallel set of fruit cells and determine what the

  largest current you can get is.

  Make a stack of alternating pennies and separated by paper towel pieces.
  Use the multimeter to find the voltage and current across the stack. Now, dampen the paper towel pieces with salt water and see the voltage and current readings. Dry toweling is an insulator while the salt water brine is a conductor. Do lemon juice or other liquids work as well as (or better than) the salt water?

  This stack of coins is a multi-celled battery just like your 12 volt car battery is really a collection of six 2- volt cells that are connected in series to add up to 12 volts.

ALTERNATIVE FRUITY BATTERIES

Oh no! You come home from work to discover there is no electrical current! Its winter and the days are getting short. You need to rig up some form of lighting so you can see what's gone wrong (or at least find your mobile to call the electricity company!). Luckily, you have items about the house to help you do this.....

How do these cells work?

There is a chemical reaction between two different types of metal electrodes and the electrolyte that connects them. Electrolytes include salty water and acids (like in car batteries). Metal electrodes pass electrons to each other through conducting wires if they are connected in a circuit. Some metals give energy away more easily than others. The electrolyte completes the circuit. This means we have a voltage because the electrical energy is flowing.

Different combinations of metal electrodes will give different voltages. Even different sizes of the same metals used will affect the voltage. The electrolyte may also affect the voltage produced. The number of cells joined together is the final factors that will affect your voltage output.

After having a look around the house, you have gathered the following equipment together:

Paper towels, selection of coins, salt, water, a lemon; a lime, an orange, a potato, a tomato, various strips of different metals, a selection of light lamps, crocodile clips, connecting wires, a voltmeter.

Your task is to make two kinds of cells (or batteries) ***– a voltaic pile*** *and* ***a fruit battery****. You will need as bright a light as possible to find the fault in the house, so you need to provide as much electrical energy to the lamp as you can. Use the voltmeter to measure the voltage from your 3 best combinations of cells/batteries. Complete the table below.*

Fruity batteries

1. Experiment with different combinations of electrode and electrolyte to find the cell that produces the highest voltage. You should work methodically and only change one variable at a time. Why is this important?

2. When you have found the best combination of fruit and electrodes, complete a table in your book to show the results from your 3 best combinations:

Highest voltages produced from electrode and electrolyte combinations Fruit/vegetable used Electrodes used Voltage (V)

Voltaic pile

3. Experiment with different combinations of metals to fins the battery that produces the highest voltage. Again, make sure you only change one variable at a time to help you work out the best combination.

4. When you have found the 3 best combinations of metals, complete the table to show your results: Highest voltages produced from different metal combinations

*Alessandro Volta was a 19th Century Italian scientist. He made the first true cell that gave a controlled current. This was an electro-chemical cell. He realised that if you have two metals (**electrodes**), separated by a liquid (an **electrolyte**), electrical energy is produced as a result of a chemical reaction between the electrodes and electrolyte. Volta used paper soaked in salty water sandwiched between circles of zinc and copper for his cell – and piled many layers up to make a battery which is known as the **Voltaic Pile.***

Combination of metals Voltage (V)

5. For each of the batteries/cells, explain how you could increase the voltages produced. Now try out your ideas and make a record of whether they worked.
6. What energy change takes place inside the batteries when they are operating?
7. Your batteries will eventually stop working. Explain why.

Homework/Extension
Find out how the following people were involved in the discovery and development of batteries:

W *Benjamin Franklin* W *Luigi Galvani*
W *William Cruickshank* W *John Daniell*

Describe their observations, experiments, problems encountered and how they were overcome.

Revision

There is a revision sheet and a set of electrical dominoes. If you cut down the middle of the sheet and then into about 10 you get an answer, then a new question underneath with a further answer. If you match them correctly your last question should give you your first answer.

AA 0.26A

0.5

A

?A

3V

V

0.5

2V

AV

Z

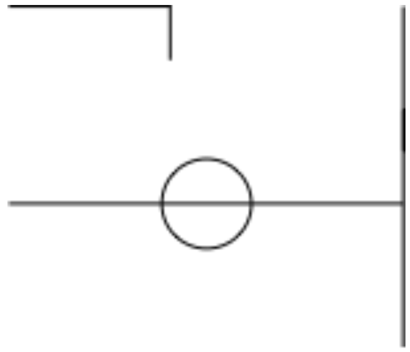
V

6V

A

6V V

Extension exercises



T 6V

1A

3A

T

? A

T

Resistance

Resistance is measured in OHMS (W)
Resistance opposes the flow of electrons or charge.

Measuring Resistance in series

PRACTICAL TASK

1. *Choose four resistors from the tray with a range of quoted values.*
2. *Using short leads and an ohmmeter find the measured resistance of each resistor and record this in the table.*
3. *Now connect two or more of the combine different resistor*

To find the total resistance in series we add up all the individual resistances $R_T=R_1+R_2+R_3$

For example what is the total of a 5W , 7W and 15W resistor in series?

R_1=5W R_2=7W R_3=15W

R_T=R1+R2+R3
R_T=5+7+15=27W

OHM'S LAW- Level 4

Ohm's law forms the basis for understanding how electrons or charge flows through circuits.

This is a very simple relationship that involves three things:

1) the voltage or the push that move electrons through the circuit,
2) the current (or amps), which is a measure of how much electrical current is flowing through that circuit as a result of

that push, and
3) the resistance (in ohms), which does all it can to make it difficult for the electrical current to flow.

Ohm's Law deals with the relationship between voltage and current in an ideal conductor. This relationship states that:

The potential difference (voltage) across an ideal conductor is proportional to the current through it.

Your task is to prove that OHM'S LAW is correct. Collect the following equipment

1. *Power supply*
2. *5 wires/leads*
3. *a multimeter set up as an ammeter*
4. *a multimeter set up as a voltmeter*
5. *one of the ceramic resistors from the*

   tray (3.3W, 5.6W, 10W , 15W, 22W)

1. *Measure the actual resistance of your chosen resistor using an ohmmeter and record this in your jotter. Remember that you do not need a power supply to do this step*
2. *Then connect up the circuit as shown in the diagram below. The power supply must be set to 0 Volts. Use the d.c supply connections (red and black).*
3. *Have your circuit checked by a teacher.*
4. *Make a table in your jotters, or preferably make a similar table in excel to record your results.*
5. *Take the readings from the Ammeter and Voltmeter for every turn of the power supply. Only take readings between 0 and 10V.*
6. *Plot a graph of voltage against current and try to find the gradient of your graph. If you use excel you can add a trendline and you can choose from the options to record the equation for the line in your graph.*
7. *If you have time repeat this for other resistors.*

0 - 10V d.c +-

A

V

Voltage Current (V) (A)

Resistance (ohms) 5.4

Here is an example of a table completed for one of the resistors with the corresponsding graph.

Voltage
(V) (A)

0.00 0.00 0.98 0.18 1.34 0.25 2.65 0.49 3.77 0.70 5.12 0.95 6.19 1.15 7.93 1.47 8.97 1.66

to give you a clue?

Resistance (ohms) 5.4

Current

It is highly unlikely that all of your points will be on the straight line. Do not plot the point 0,0 on your graph

QUESTIONS/ EVALUATION

1. What do you notice about the value of the current when the voltage increases?

2. *What do you notice about the gradient of your graph?*
3. *Why might your graph not go through (0,0)? Look at the equipment*

4. You should have found out one of the most important formula for electrical current, and that is that the Voltage is equal to the current mulitplied by the resistance or as we would usually write it

$$V = IR$$

where V=voltage or potential difference measured in volts I= current measured in amp and R= resistance measured in ohms

Now try these questions

1. *If there is a current of 3A through a 2.5W resistor, what is the voltage across the resistor?*
2. *A voltmeter across a power supply reads 12V, this is connected to a 6W resistor. What current would there be through the resistor?*
3. *What is the resistance of a resistor if a voltmeter across it reads 4V and the current in the resistor is 0.2A?*

10.00 9.00 8.00 7.00 6.00 5.00 4.00 3.00 2.00

1.00 0.00

0.00 0.20 0.40

0.60 0.80 1.00 1.20 Current (A)

1.40 1.60 1.80

y = 5.4x R2 = 1

OHM'S LAW EXPERIMENT

Voltage (V)

Lesson 16+ Design and Build

Aims for lesson 16- Design and Build

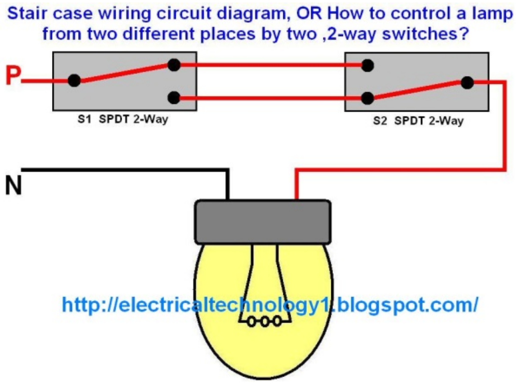
• equipment handling
• Design/ construct/ test and modify • Risk Assessment
• Diagram
• Problem solving

• observing

There are various examples of circuits that the students can build.
RULES- unlike 2 in the picture it has to be an electrical circuit (not a pool table or an electrical chair unless it really lifts!) Someone really did make this running machine from Lego!
For example,

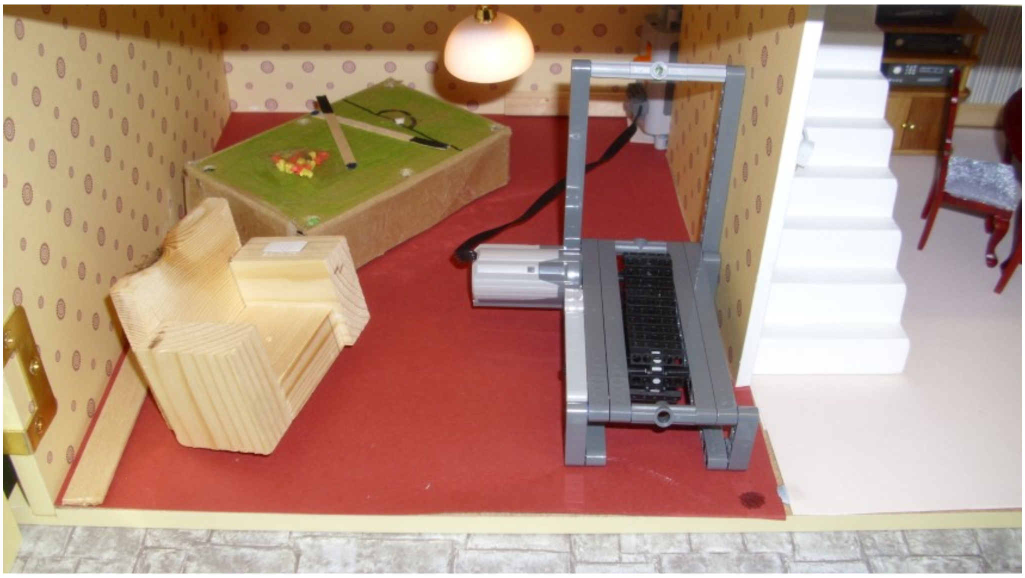
- can they make a front and back door bell, either switch must operate the bell
- make a two way stair light for lighting the bottom and top of the stair, this will require 2 two way

  switches



- .BBQ see photos
- Microwave (see photos)
- Fridge with a light that comes on as the door is opened.
- Door Bell
- Burglar Alarm

We also have some electronic boards that the students can use. I will try to make up some sheets to explain how these work, unless someone wants to help me with this.



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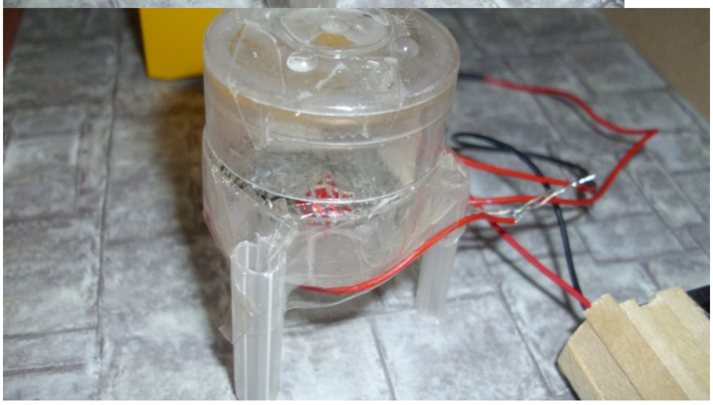
SYLVANIA
25W



Any concerns if the circuit is safe or buildable see Mrs H or Mr H, or set it up and don't turn it on until it is checked. I am afraid I can't find the excellent fridge that was made. This had a door where the light came on as the door was opened. Students brought in clay to make the food. Great fun and great Physics!

Don't forget to wear your badge if you get through the course and certificate of completion!

Appendix 1

Storyline for the Ohm Comforts Programme
Terry & June Easdale are purchasing a brand new house in the Lockerbie Area. The survey report is in and they have contacted Whm CWmfWrts to provide them with additional comforts for their house.
You are to design and build one or more of the following to help the Easdales.
For each circuit you need to include a plan, circuit diagram, description, and photo of what you did. Record any information that you learned as you put together the material. Can you cost the project for the Easdales?

1. Design a door bell circuit that can work from the front and back door.
2. A set of lights for the outside of the house for their house warming party celebrations. It is also

   nearly Christmas and they might want to celebrate that too.

3. Currently there are several flight of stairs in the house and no stair lights (this was pointed out in the

   survey as very dangerous). Can you design a stair light that can be switched on and off from either

   the top or the bottom of each flight of stairs.

4. The Easdales are worried about their security. What circuits can you build to deter burglars?
5. MAKE UP YOUR OWN CIRCUITS that would improve the quality of life for the Easdales in their

   new home.

Appendix 2

Magnox Cottage, 23 Ulverston Way Walton, Lockerbie, CU2 8RS

A delightful detached three and a half storey dwellinghouse situated in a prominent position in a well established residential area convenient for town centre and local amenities. The property has a bay front window and offers flexible accommodation. The house benefits from a basement with separate entrance with potential for conversion to a granny flat. The house has gas central heating, lead effect glazed windows and beautifully presented patio. The property is situated in a sought after residential neighbourhood, in the Lockerbie Academy catchment area.

Offers in the region of £247.490

For further information contact: The seller Ms D Barton or the agent on

Tel: 01229 231707

Lockerbie is a busy town which gives easy access to the nearby M74 motorway. There is a wide range of local amenities including church, library, railway station, shops, hotels, and various leisure activities.

ACCOMMODATION comprises

Entrance

Climb up a flight of 6 stairs and enter via a wooden front door with leaded windows. The entrance hall connects to the kitchen and dining room

Kitchen

3.22m by 3.96m

The house benefits from a fitted kitchen. The kitchen has one window to the front with leaded glass. The light is of rise and fall style.

Dining Room

A separate large dining room 4.25m by 3.96m with a bay window to the front with leaded windows. Fitted carpets and ceiling light

Stairs from the dining hall lead to the third floor. Sitting Room

Jules Watt & Partners

Solicitors & Estate Agents

3.22m by 3.96m. Double glazed leaded window to the front, spectacular Georgian fire place with electric fire; polished brass wall lights with white shades either side of the fireplace; fully fitted carpet.

Bedroom 1

4.26m by 3.96m. Double glazed leaded windows with fitted carpet.

Stairs from the third floor lead to the attic floor

Bathroom

3.28m by 3.96m. Dormer leaded windows.

Three piece white suite comprising w.c., pedestal sink and bath connected to full services; fitted carpet; wall mirror and shaving point

Bedroom 2 / Nursery

4.32 by 3.96m
Dormer leaded windows; fitted carpets



BASEMENT
Bedroom 3 /Games Room/ Granny flat 4.21m by 4.72m
Large leaded window to front; fitted carpet.

Office / Granny flat/ Snug

3.24m by 4.73m
Large leaded window to front; fitted carpet

OUTSIDE

GARDEN

A lower level terrace, good for alfresco dining.
Drying area
Secluded paved seating area to the front which can be a sun-trap.

Notes

Council Tax Band F.

Services

Mains water, electricity, gas and drainage. The telephone may be taken over subject to the usual British Telecom regulations.

Burdens

The subjects are sold subject to the burdens and conditions and others contained or referred to in the title deeds or otherwise affecting the same.

OFFERS

A closing date for offers may be fixed therefore it would be most advisable for prospective purchasers to register their interest with the Selling Agents.

ENTRY

Entry as may be arranged. Interest at the rate of 5% above the Royal Bank of Scotland Base Rate will be payable on the price from the date of entry to the date of settlement notwithstanding consignation.

We, Jules Watt & Partners, the Agents, have not tested any structures, apparatus, equipment (electrical or otherwise), fixtures, fittings or services and therefore cannot verify that they are sound, in working order to fit for purpose, and room sizes are not guaranteed. Prospective purchasers are advised to have any matters critical to their needs, verified by their Solicitor, Surveyor or appropriate adviser.

The details presented have been carefully prepared by the solicitor acting for the seller of the property and they are believed to be correct, but are not guaranteed and are not in themselves to form the basis of any contract. Purchasers should satisfy themselves on the basic facts before a contract is concluded

Laura, Biology teacher

National 4/5
L West

<u>National 5 Biology</u>

Name :

What grade do you want to achieve why?

Which skills do you want to acquire or develop?

How will you achieve this grade and these skills?

What potential barriers might you face throughout the year?

How will you overcome these barriers?

Revision of Level 4 content:

- Reproduction (plants and animals)
- Inheritance
- Mitosis and ethics
- Enzymes
- Biotechnology
- Aerobic respiration
- Biodiversity
- Body Balance

Reproduction:

Name the different gametes in animals. Describe their structure and how they are suited to their job.

What is the function of the umbilical card, placenta and amniotic fluid.
How could lifestyle choices e.g. taking drugs affect an embryo

Describe the process of fertilisation including where it occurs in the female. What is a zygote

Why is internal fertilisation important to animals?
What is external fertilisation?
Compare survival rates of organisms who use internal vs external fertilisation

Draw and label the female reproductive system.
Draw and label the male reproductive system.

What changes take place during puberty. When do growth spurts occur.

Inheritance:

Give a definition of 2 types of inheritance with examples. Which graph should be used to display each type.

What do the genetic terms dominant and recessive mean. When would we use a punnet square? Cross Rr and Rr, what offspring are expected?

What is selective breeding? Give examples of characteristics. Give disadvantages of selective breeding. What is cloning?

How do we inherit characteristics from how parents.
How is sex determined?

What is the method to extract DNA from strawberries

What is meant by a species, fertile and sterile.

Enzymes:

What is a biological catalyst? Give some examples.

How do enzymes work? Use diagrams to explain.

What does enzyme specificity mean?

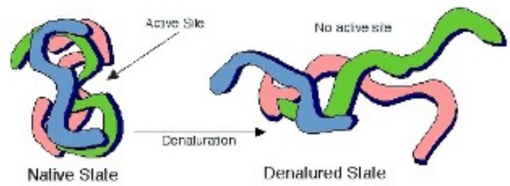
Give examples of commercial uses of enzymes.

Outline a practical investigation to measure the effect of temperature on enzymes.

What's the difference between non-bio and bio washing detergents?

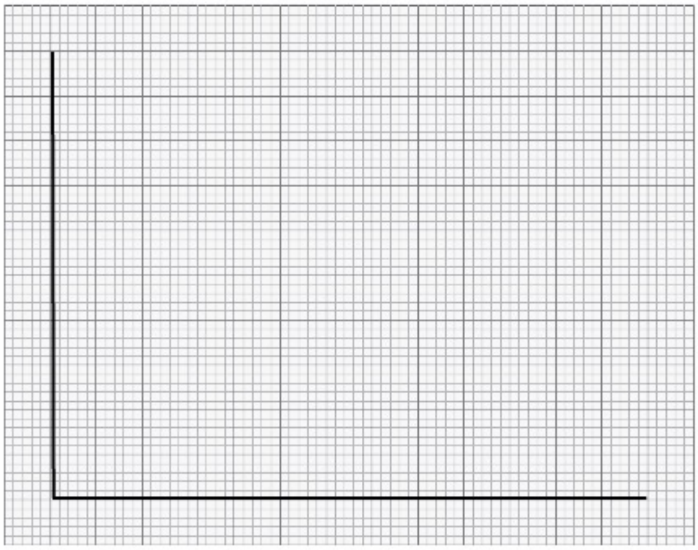
What is meant by optimum conditions?

The effect of temperature on enzyme action



Normal human body temperature =

Temperature °C	Reaction rate
10	1.0
15	1.5
20	2.5
25	3.5
30	5.5
35	7.5
40	9.5
45	8.5
50	7.0
55	4.0
60	0.0



Describe what this graph is telling you?

2 marks

Respiration:

What is the equation for respiration?

Why do cells need energy

What happens to limewater in the presence of carbon dioxide?

What happens to cobalt blue paper in the presence of water

How can the rate of respiration be measured? Think about the equation!

What is a respirometer ?

Why do scientists use yeast in investigations?
What affects the rate of respiration in yeast?

What is anaerobic respiration, include equations for animals and plants.

Biodiversity:

Define the following terms population, community, niche, species

Describe how the removal of a single species would affect all other species, give examples.

List structural, physiological and behaviour adaptations for a plant and a animal

Describe examples of learned behaviour. Outline a method to investigate behaviour in woodlice.

Describe the impact of over using fertilisers.

How would a natural disaster e.g. an earthquake affect biodiversity

What affect does the increasing world population have on biodiversity

Body balance:

What is the definition of Homeostasis?

What changes occur in the body when it is too cold?
What changes occur in the body when it is too hot?

Draw a diagram showing changing levels of blood glucose, insulin and glucagon over a period of time.

Where do humans gain water from and how do we loss water from our bodies?
What hormone controls water levels within our bodies? Draw a diagram to show its effects

Describe what diabetes is and how it might affect an individual

What does an enzyme do? State 3 facts about enzymes?

What is osmosis? Remember to use the full definition!

Functions

Structure	Function	Animal	Plant
Cell Membrane			
Nucleus			
Cytoplasm			
Ribosomes			
Mitochondria			
Vacuole			
Cell Wall			
Chloroplasts			

Organelle	Cells present in	Function
Cell wall		
Mitochondria	Animal, plant and fungal	
Chloroplasts	Some plant cells	
		Controls the movement of substances in and out of cells
Cytoplasm	All cells	
Vacuole	Plant and fungal	
Nucleus		Controls cell activities and contains genetic information
Ribosome		Site of protein synthesis
Plasmids		Small circular DNA

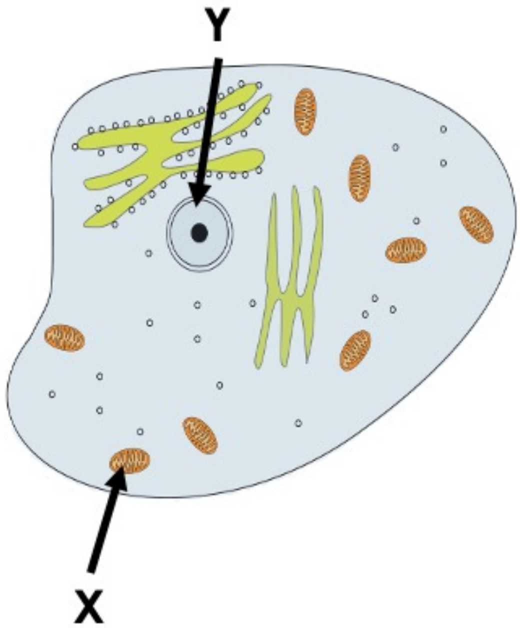
Check Test

1. What type of cell is shown in the diagram opposite?

2. How can you tell?

★ 3. What name is given to structure X?

4. What is the function of structure Y?



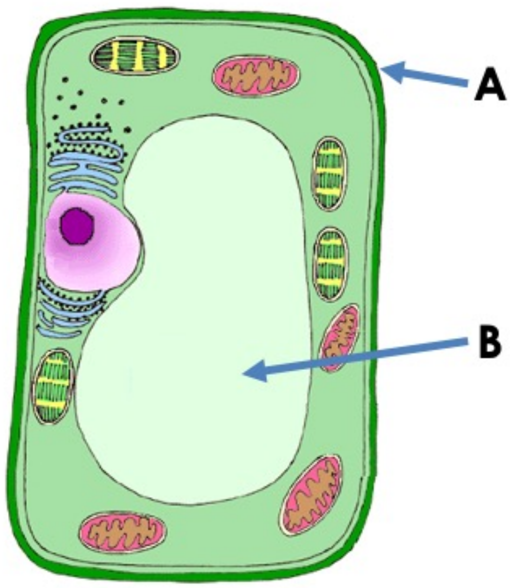
Check Test

5. Give an example of a fungal cell.

6. Name structure A.

7. What is the function of structure B?

8. How can we tell this is a plant cell?



Questions:

1. Why was the egg shelled removed?
2. Why did you dry the eggs with a paper towel before weighing them?
3. Why is it a good idea to compare the percentage change in mass of each egg, rather than the change in mass?
4. What happened to the egg placed in the 20% sodium chloride solution?
5. Explain why the mass of the egg changed in this way?
6. What happened to the egg in 0% salt solution (distilled water)?
7. Explain why the mass of the egg changed in this way?
8. What do you think about eggs like this as a model for showing osmosis in animal cells
9. Are there any problems with this as a model for animal cells.

Osmosis and cells

Learning intention:

Apply knowledge of osmosis to plant and animal cells placed in different concentration.

Starter:

2. Which line in the table below identifies correctly the importance of diffusion to an animal cell?

	Raw material gained	*Waste product removed*
A	oxygen	glucose
B	carbon dioxide	oxygen
C	oxygen	carbon dioxide
D	glucose	oxygen

DNA Problem Solving

There are 1000 bases in a section of DNA.

a) 275 of the bases are cytosine, how many of the bases are guanine?

b) How many of the bases are adenine?

c) How many of the bases are thymine?

d) Display this information in a table.

DNA Problem Solving

There are 650 bases in a section of DNA.

a) 150 of the bases are adenine, how many of the bases are thymine?

b) How many of the bases are cytosine?

c) How many of the bases are guanine?

DNA Problem Solving

$$\text{Percentage} = \frac{\text{Number}}{\text{Total}} \times 100$$

A section of DNA contains 500 bases in total, 150 of these are adenine. What percentage of the DNA is adenine?

150 ÷ 500
= 0.3
0.3 x 100
= 30%

DNA Problem Solving

1. A section of DNA contains 500 bases in total, 100 of these are cytosine. What percentage of the DNA is cytosine?

2. A section of DNA contains 600 bases in total, 150 of these are guanine. What percentage of the DNA is guanine?

3. A section of DNA contains 500 bases in total, 150 of these are adenine. What percentage of the DNA is ***cytosine***?

Check Test

1. **What are genes made up of? (1)**
2. What is the function of DNA? (1)
3. **Describe the structure of DNA. (1)**
4. Which base pairs with guanine? (1)
5. **Which base pairs with thymine? (1)**
6. What is the 'genetic code'. (1)
7. **What determines the sequence of amino acids which make up a protein? (1)**

Check Test

8. **Where are proteins synthesised?**
9. What is the name of the molecule responsible for carrying a copy of the code?
10. **There are 745 bases, 149 of them are cytosine.**

(i) How many are guanine? (1)

(ii) What percentage are cytosine? (1)

(iii) What percentage are thymine? (1)