An investigation into the use of the Bridge21 model to deliver the new Junior Cycle Science specification.

A dissertation submitted to the University of Dublin, in partial fulfilment of the requirements for the degree of Master of Science in Technology & Learning.

Declaration

I declare that the work described in this document is, except where otherwise stated, entirely my own work and has not been submitted as an exercise for a degree in any other university.

Signed: ____________________________________

Mairead Glynn

A dissertation submitted to the University of Dublin, in partial fulfilment of the requirements for the degree of Master of Science in Technology & Learning

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Abstract

There are many challenges in STEM education including: a declining number of students considering careers in STEM, the use of didactic teaching styles, the restriction of traditional classroom environments, overloaded curriculum content, a lack of discussion of topics of interest and the absence of opportunity for creative expression.

In September 2016, the Irish National Council for Curriculum and Assessment (NCCA) introduced the new Junior Cycle Science specification for years 1-3 in Secondary Schools (ages 12-15 years). The Science specification consists of four contextual strands: Physical world, Chemical world, Biological world and Earth and Space. The four strands are overarched by one unifying strand, the Nature of Science. The Nature of Science is both a way of thinking and a collection of practices that scientists use to develop and evaluate knowledge (Flick & Lederman, 2006). Inquiry is a foundational principle in the Nature of Science. There is no specific content linked to the Nature of Science strand, its learning outcomes are underpinned by the activities and content in the contextual strands.

The new science specification is informed by the Framework for Junior Cycle document. This document will guide the implementation of the Junior Cycle in Irish schools and will inform the specification for each Junior Cycle programme. The Framework outlines eight key skills, and twenty-four statements of learning, that focus on the student's acquisition of 21st century competencies.

Inquiry Based Learning (IBL) is a teaching strategy often utilised in the STEM disciplines. This involves inquiry orientated instruction that engages students in the investigative nature of science. The characteristics of IBL greatly overlap with the defining characteristics 21st century teaching and learning. 21st century skills are transversal, multidimensional and associated with higher order skills and behaviour that represent the ability to cope with complex problems and unpredictable situations. It is argued that the teaching and learning of 21st century skills, such as those in the new Junior Cycle Science specification, cannot easily be achieved in conventional classroom settings where didactic pedagogy predominates. It is further argued that an alternate pedagogical model is required to successfully implement a 21st century framework and curriculum. Research indicates

that a social constructivist, collaboration enabled pedagogy would positively affect students' engagement with science and nurture the development of 21st century competencies.

Bridge21 is a learning model that involves moving away from teacher centred pedagogy and is designed to release the potential of student led, inquiry based, collaborative, technology-mediated learning. This dissertation uses the Bridge21 model to develop and implement lessons, underpinned by Inquiry Based Learning strategies, to achieve certain learning outcomes on the new Junior Cycle Science specification. This research examines the impact of using the Bridge21 learning model with a focus on student attitudes to science and the development of 21^{st} century competencies.

A mixed methods case study (Creswell, 2003) methodology was used for this investigation. Two validated questionnaires were adapted for quantitative data capture. Survey One (Appendix E) is a modified Attitudes toward STEM survey (S-STEM) which used Likert-scale items to measure students attitudes towards Science (Friday Institute for Educational Innovation, 2012). Survey Two (Appendix F) a validated 21^{st} Century Key Skills questionnaire (Ravitz, Jason, et al., 2012) is used to measure students attitude toward 21^{st} Century Key Skills. Focus groups provided rich qualitative data for triangulation.

The findings from the data show changes in students' attitudes to science, evidence is presented in relation to the development of 21^{st} Century Skills after the learning experience in science was delivered. The qualitative data provides a context for the findings and through congruence with the quantitative data the conclusions reached in this case study are supported.

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Chapter One: Introduction

1.1 Challenges to STEM Education

The challenges that exist in STEM education are well documented (McDonald, 2016; Said, 2016; Lindahl, 2003; Osborne & Collins, 2000; Osborne & Dillon, 2008; Wickham, Girvan and Tangney, 2016). Contributing factors include; the use of didactic teaching styles, the restriction of traditional classroom environments, low student motivation, overloaded curriculum content, over emphasis of text books, a lack of discussion of topics of interest and the absence of opportunity for creative expression

Many of the effective approaches used when teaching STEM disciplines share common elements; inquiry orientated instruction that engages students in the investigative nature of science and the active search for knowledge and the understanding to satisfy a curiosity (Haury, 1993; khishfe & Abd-El-Khalick, 2002; Harris & Rooks, 2010;). These approaches to STEM education are supported by educators and policy makers as it is understood that they contribute to deepening students' understanding of content (Kuenzi, 2008). It is further argued that this form of STEM education inspires students to be actively engaged in learning and help them realise the meaning of learning specific content (Meyrick, 2012). Unfortunately, the number of students considering careers in the STEM discipline is declining (Henriksen, Dillion & Ryder, 2015). STEM disciplines lead to some of the most versatile and important careers in the contemporary world- most initiatives that are making the world a better place to live in are from the contributions of STEM fields (Hossain & Robinson, 2012). Many of the challenges humanity faces will require major contributions from the scientific community (NCCA, 2013). However, less than one-third of students in Ireland expect to be in a science-related career at age 30 (Shiel, Kelleher, Mckeown, and Denner, 2015).

1.2 Curriculum Content and Pedagogical Approaches

The last decade has seen a shift in education, both nationally and internationally, from content to skills driven curricula. These skills are referred to as 21st century skills or competencies, and are considered necessary for students to take their place in a knowledge society (Voogt & Roblin, 2012; Johnson et al. 2015). Many countries have developed 21st century frameworks for education including EU member states, OECD countries, USA, Japan and Korea, amongst several others. Several of the 21st century frameworks that have been proposed (Dede, 2010; J. Voogt, Erstad, Dede, & Mishra, 2013; Joke Voogt & Roblin, 2012) share many common competencies including: collaboration, communication, ICT literacy, critical thinking skills, contextualised learning and problem solving activities. These 21st century skills are transversal, multidimensional and associated with higher order skills and behaviour that represent the ability to cope with complex problems. It is argued that to cultivate these skills a guided discovery and a learner centred approach should be prioritised over a teacher centred, transmissive pedagogy (McDonald, 2016; Meyrick, 2011; Wickham, 2015).

Teaching strategies considered best practice in STEM education include Inquiry Based Learning and Problem Based Learning (STEM Education Review Group, 2016). Inquiry orientated instruction engages students in the investigative nature of Science (Haury, 1993) and requires the learning engage in activities and develop skills. However, the focus is on the active search for knowledge or understanding to satisfy a curiosity (Harris & Rooks, 2010). Problem Based Learning (PBL) is a teaching strategy where students work collaboratively to solve complex problems that help develop content knowledge as well as problem solving, reasoning and communication skills (Savin-Baden, 2000; Whitcombe, 2010; Beaumont, Savin-Baden, Coradi & Poulton, 2014). The characteristics of IBL and PBL greatly overlap with the defining characteristics of 21st century teaching and learning.

The teaching and learning of 21st century skills is difficult to achieve in conventional classroom settings (Tangney, B., Bray, A., & Oldham, E., 2015) or in the absence of effective technology (Ertmer & Ottenbreit-Leftwich, 2010). The new Junior Cycle science programme requires students to reach discrete learning outcomes identified in each strand. The overarching aim of the Junior Cycle is for students to develop eight key skills and fulfil twenty-four statements of learning as a result of their studies in each subject. In order to achieve this aim, an alternative pedagogical model such as the Bridge21 is required to successfully implement a 21st century framework and curriculum. This is outlined in detail in the next section.

1.3 Bridge21

Bridge21 is an innovative approach to learning for secondary education (Lawlor J, Marshall K., & Tangney B., 2015). The Bridge21 model is based on a social constructivist pedagogy and its approach to teamwork is influenced by the patrol system of the World Organisation of the Scout Movement. Bridge21 created an effective environment for technology mediated learning, both in and out of school, across a variety of subjects (O'Donovan, McCrea, Gallagher & Tangney, 2016). This learning model involves moving away from teacher-centred pedagogy and is designed to release the potential of student led, collaborative, technology mediated learning (Sullivan, Marshall and Tangney, 2015). Results from various deployments of the Bridge21 model indicate that it has a positive impact on students' intrinsic motivation and their attitudes towards taking personal responsibility for their learning (Johnston, Conneely, Murchan and Tangney, 2015; Lawlor, Marshall and Tangney, 2015; Wickham, Girvan and Tangney, 2016).

1.4 The Role of ICT in Education

The role of digital technology is intrinsic to 21st century teaching and learning. Its capacity to open diverse pathways for students to construct and engage with knowledge is well documented (Fullan & Langworthy, 2014; Sánchez, Salinas, Contreras and Meyer, 2011; Dede, 2010; Ertmer & Ottenbreit-Leftwich, 2010; McGarr, 2009; Jonassen, Carr & Yueh, 1998). The integration of ICT into education is an important factor for both teachers and students in order to perform effectively in a 21st Century teaching and learning setting (Voogt & Roblin, 2012; Pineida, 2011). Ertmer & Ottenbreit-Leftwich (2010) contend that the teaching profession has not yet integrated technology into its practice with same success as other professions. Many teachers use technology for presentation software, learner-friendly websites and management tools to enhance existing practice rather than to support inquiry, collaboration and reformed practice (Harris, Mishra & Koehler, 2009). Although infrastructure can be an issue in some schools, simply equipping schools with the essential ICT tools does not improve the quality of instruction and does not create a more effective learning environment (Gülbahar & Güven, 2008). There are many other factors that influence a teacher's use of ICT including pedagogical orientation, ICT competency, professional engagement, self-efficacy, subject, school culture and time constraints. This list is not exhaustive (Voogt, 2010; Ertmer, Ottenbreit-Leftwich, 2010; NPAC, 2006).

The most recent initiative launched by the Irish government, the *Digital Strategy For Schools 2015,* invests €210 million towards technology in education. This investment is being made against the backdrop of the systemic reform of the Junior Certificate to the Junior Cycle. The Junior Cycle is a 21st century framework for learning that emphasises ICT as an integral part of the students learning, consequently there is more motivation than ever before for teachers to integrate technology into their practice.

1.6 Research Question and Sub-Questions

The Bridge21 learning model involves moving away from teacher centred pedagogy and is designed to release the potential of student led, inquiry based, collaborative, technology-mediated learning. An important point emphasised in the literature relating to the Junior Cycle Science specification is the importance of inquiry-based teaching and learning when achieving the intended learning outcomes (NCCA, 2013 and NCCA, 2015). The consultation report (NCCA, 2014) highlights that an inquiry-based approach would be necessary to achieve the aims of the new Junior Cycle Science specification. Using the Bridge21 model to implement a 21st Century curriculum, such as the new Junior Cycle Science curriculum, could positively affect students' engagement with science and simultaneously nurture the development of 21st century competencies.

1.6.1 Research Questions

In light of the above, this dissertation uses the Bridge21 model to develop and implement lessons, underpinned by Inquiry Based Learning strategies, to achieve certain learning outcomes listed on the new Junior Cycle Science specification. This leads to the following research question-

Does the Bridge21 model offer an effective practice when delivering aspects of the new Junior Cycle Science specification?

This gives rise to additional sub questions for consideration in this study:

- Did the learning experience have a positive or negative effect on the students' attitudes to science?

- What aspects of the Bridge21 model positively or negatively influenced the students learning experience in science?

1.6.2 Overview of Dissertation

Literature Review

The literature review chapter presents a historical context for the current Science curriculum offered at post primary level in Ireland. The review examines the development of the new Junior Cycle Science specification and its link to the framework for Junior Cycle, a 21^{st} century learning framework. The Bridge21 model is outlined and its benefits are discussed under four headings; classroom partnership, technology, teamwork and inquiry based learning. The challenges and opportunities that exist for teachers delivering a 21^{st} century science curriculum are also outlined. Evidence is presented for the use of the Bridge21 model that combines social constructivist pedagogy with constructionist and contextualised learning activities. Enabling learners to actively construct their own artefacts, which they share with others, can lead to improved understanding and engagement. The research further suggests that the strategies utilised as part of the Bridge21 learning experience will facilitate students' development of 21^{st} Century skills.

Design of the learning experience

The design chapter outlines how the learning experiences were informed by the literature review. It also presents an overview of the design of each learning activity and examines the key skills and learning outcomes it is anticipated that the activity will achieve or partially achieve. Finally, the chapter outlines how each element of the Bridge21 model was incorporated into the learning activity.

Methodology

A mixed methods case study (Creswell, 2003) methodology was used for this investigation. Two validated questionnaires were adapted for quantitative data capture. Survey One (Appendix E) is a modified Attitudes toward STEM survey (S-STEM) which used Likert-scale items to measure students attitudes towards Science (Friday Institute for Educational Innovation, 2012). Survey Two (Appendix F) a validated 21^{st} Century Key Skills questionnaire (Ravitz, Jason, et al., 2012) is used to measure students attitude toward 21^{st} Century Key Skills. Focus groups provided rich qualitative data for triangulation.

Findings

Chapter Five presents the results of the data analysis and discusses the findings that arise. The data analysis has led to findings that support the use of a social constructivist pedagogy with an inquiry based approach such as Bridge21. The use of the Bridge21 model to deliver the learning experience used in this research study has positively impacted students engagement in science and statistically significant impact on students confidence in the Key Skills examined; collaboration, using technology, critical thinking, creativity and innovation and self-direction.

Conclusions

As a result of the findings conclusions to the research questions are enabled. Changes in students' attitudes to science are discussed and conclusions on the merits of using the Bridge21 model to deliver the new Junior Cycle Science Specification are considered.

Chapter Two: Literature Review

2.1 Introduction

This chapter presents a historical context for the current science curriculum offered at post primary level in Ireland. The review examines the development of the new Junior Cycle Science specification and its link to the framework for Junior Cycle. Considering the challenges that exist for science teachers implementing a 21st century curriculum, Bridge21 is examined as an alternative pedagogical model. The Bridge21 model and its benefits are discussed under four headings; classroom partnership, technology, teamwork and inquiry based learning.

2.2 Junior Cycle Framework

The last decade has seen a shift in education from content to skills driven curricula. These skills are referred to as 21st century skills or competencies and are considered necessary for students to take their place in a knowledge society (Voogt & Roblin, 2012; Johnson et al. 2015). Many countries have developed 21st century frameworks for education including EU member states, OECD countries, USA, Japan and Korea among others. Several of the 21st century frameworks that have been proposed (Dede, 2010; J. Voogt, Erstad, Dede, & Mishra, 2013; Joke Voogt & Roblin, 2012) share many common competencies including; collaboration, communication, ICT literacy, critical thinking skills, contextualised learning and problem solving activities. These 21st century skills are transversal, multidimensional and associated with higher order skills and behaviour that represent the ability to cope with complex problems.

Voogt and Roblin (2012) identify three different approaches to guide the curricular integration of 21st century competencies. These approaches may adopted in the following ways:

a) To existing curriculum as new subjects or as new content within traditional subjects.
b) Integrated as cross-curricular competencies that both underpin school subjects and place emphasis on the acquisition of wider key competencies.
c) Form part of a new curriculum in which the traditional structure of school subjects is transformed.

In Ireland the latter approach was adopted- a new curriculum in which the traditional structure of school subjects is transformed. Only history will tell if this was the correct approach to integrate 21st century competencies. The Junior Cycle reform has been fraught with controversy and garnered widespread media attention (Erduran and Zoubeida, 2014). Teacher unions, which represent teachers as one of the major stakeholders in education, resisted many of the changes outlined in the initial Framework for Junior Cycle published in 2012, citing lack of resources and the absence of an externally assessed terminal exam among the reasons for the resistance to change. The finalised framework for Junior Cycle, published in 2015, outlines the key educational changes that the Department of Education and Skills (DES) is putting in place for the first three years of post-primary education. Eight principles, twenty-four statements of learning and eight key skills will guide each programme of study. This represents a dramatic change from the previous syllabus teachers had become experienced in delivering. Such a dramatic change would only be successful if supported by intensive in-service and training in new pedagogical models that support a skills driven curricula.

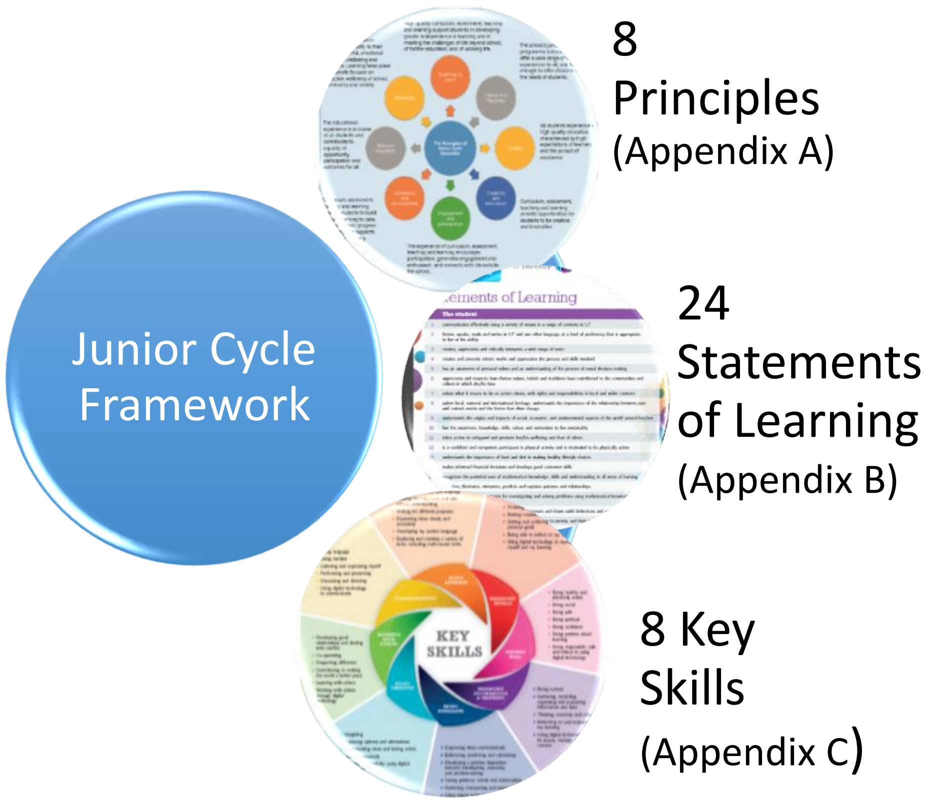


Figure 1 Key Elements of the Junior Cycle Framework, relevant to each subject specification

2.3 An Overview of Junior Science Education in Ireland

2.3.1 Junior Certificate Science

When the Junior Certificate Science (12-15 years) course was introduced in 1989, there were two options within the science syllabus, science without local studies or science with local studies. Science without local studies was assessed externally via a terminal written exam only and science with local studies was assessed via a terminal exam and an investigative project both of which were externally assessed. The syllabus was presented as a list of content with no clear learning objectives associated with the content (NCCA, 2006). The emphasis of the 1989 Junior Certificate science syllabus was on the students' experiencing science as a practical activity (Department of Education and Skills (DES), 1989). This course was revised and a new syllabus was introduced in 2003 due to the declining numbers of students opting to study science to leaving certificate level (DES, 2002; Politis, Killeavy & Mitchell, 2007; Kennedy, 2013). In an effort to move the study of Junior Certificate science towards "doing" rather than the "observing or learning off" of Science (NCCA & DES, 2006). This approach was also observed internationally (Alpaslan, Yalvac & Loving, 2015).

The 2003 revised Junior Certificate syllabus intended to emphasise an investigative approach to science (NCCA & DES, 2006). To reflect this aim, science was assessed via a terminal exam worth 65% of the overall mark, with a further 10% for 30 mandatory practical activities, divided evenly among Chemistry, Biology and Physics (coursework A) and a final 25% for a report on two practical investigations prescribed by the State Examinations Commission (SEC) or one extended investigation of the student's own choice. This was the first time in Ireland practical work was mandatory at junior level (Kennedy, 2013). Unlike the 1989 course, the 2003 science syllabus was presented with a list of aims, objectives and associated learning outcomes, '*which encompass the knowledge, understanding and skills that students can be expected to attain through their study of Science'* (NCCA & DES, 2006).

A report prepared for the Department of Education on the Implementing the Revised Junior Certificate Science Syllabus by Eivers et al (2006) stated that 87% of the science teachers surveyed reported an increase in their use of an investigative approach. However, many teachers expressed concern that the curriculum was overloaded with content and this negatively affected their ability to engage in IBL or with an investigative approach.

The Background Paper and Brief for Junior Cycle Science (2013) argues that the revised Junior Certificate syllabus (2003) did not meet its aims, as Ireland's performance in Science by PISA ranking did not show any discernible improvement in 2009 when compared with 2000 and 2003. However, the 2012 PISA results did rank Ireland 9th out of 34 OECD countries, up five places since 2009 (DES, 2013). It is suggested in the ESRI report (2016) that science scores may well have been potentially higher in 2009, but were reduced by some of the factors that may have affected performance on reading literacy and mathematics. Unfortunately, Ireland's mean score dropped to 502.6 in 2015, ranking Ireland 13th among OECD countries.

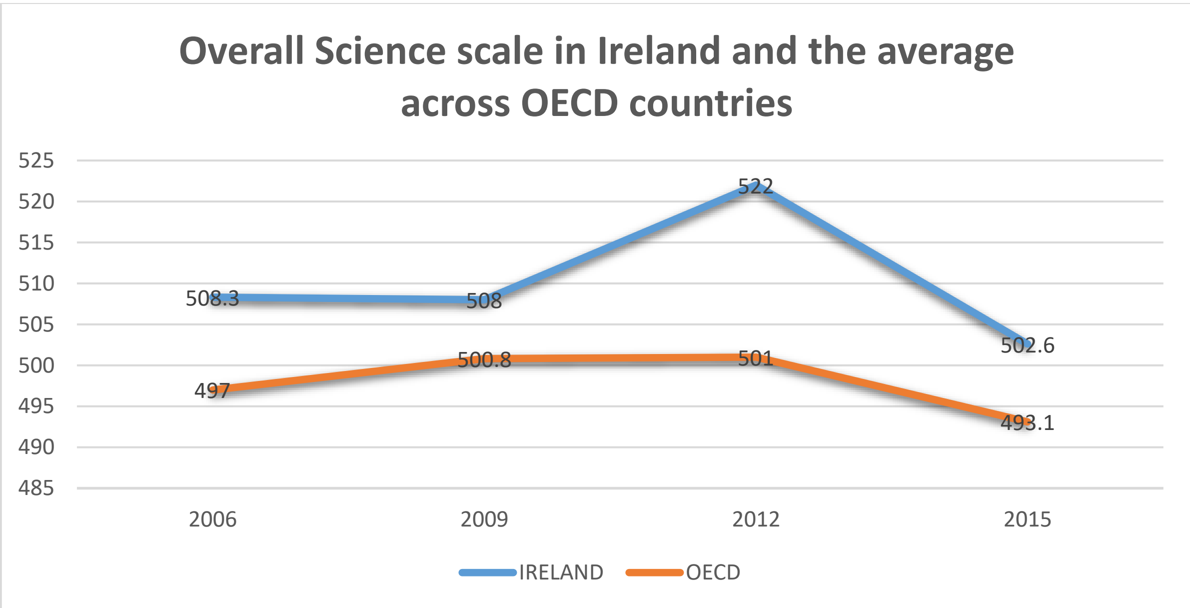


Figure 2 Mean scores on the overall Science scale in Ireland and the average across OECD countries, 2006-2015

2.3.2 Junior Cycle Science

The new Junior Cycle specification was published by the NCCA in 2015 as part of the overall Junior Cycle reform process and was introduced into schools nationally in 2016. The science specification consists of four contextual strands: Physical world, Chemical world, Biological world and Earth & Space. The four strands are overarched by one unifying strand the Nature of Science. There is no specific content linked to the Nature of Science strand, its learning outcomes underpin the activities and content in the contextual stands.

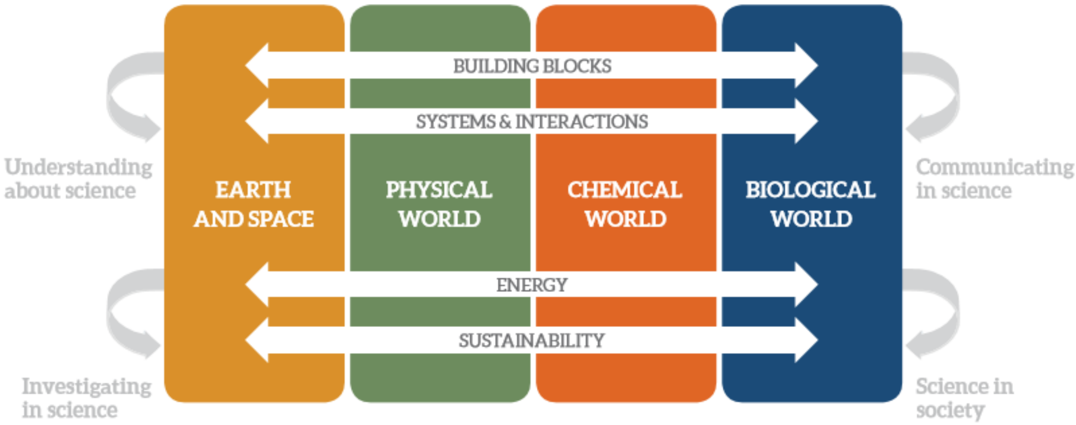


Figure 3 The elements of the contextual strands and the unifying strand, showing the integrated nature of the specification (NCCA, 2015).

Each contextual strand is accompanied by 8 to 10 learning outcomes or statements that describe the understanding, skills and values students should be able to demonstrate (Appendix D). The development of 21st century skills and fulfilling the statements of learning is intended to take place in the context of the learning outcomes rather than a separate entity. Unlike previous syllabi, the learning outcomes for this specification describe what the students should be able to do, as opposed to what the teacher should teach.

For example:

> *"Students should be able to investigate patterns and relationships between physical observables"* Learning outcome for Junior Cycle Science (2015), strand four Physical world.

Compared to:

> *"Students will be able to investigate the relationship between the extension of a spring and the applied force"* Learning outcome for Junior Certificate Science (2003), Physics.

An important point emphasised in the literature relating to the Junior Cycle Science specification is the importance of inquiry-based teaching and learning when achieving the intended learning outcomes (NCCA, 2013 and NCCA, 2015). The consultation report (NCCA, 2014) highlighted that an inquiry-based approach would be necessary to achieve the aims of the new Junior Cycle Science specification. The Professional Development Service for Teachers (PDST) stated that the *"linkage between Science and the key skills are rooted in inquiry, process knowledge, experimental design and scientific reasoning……it is method that must be at the heart of any new curriculum-not rote learning*" (NCCA, 2014). Achieving this link and delivering lessons that develop students 21st century skills will be difficult to achieve without an appropriate pedagogical model.

2.4 Bridge21

2.4.1 Overview of Bridge21

Bridge 21 is an innovative approach to learning for secondary education (Lawlor J, Marshall K., & Tangney B., 2015). The Bridge21 model is based on a social constructivist pedagogy and its model for teamwork is influenced by the patrol system of the World Organisation of the Scout Movement. Constructivism is a learning theory that argues learners generate knowledge by constructing their own learning rather than passively accepting knowledge delivered by other sources (Greene, 2005).

The learning model involves moving away from teacher centred pedagogy and is designed to release the potential of student led, collaborative, technology mediated learning (Sullivan, Marshall and Tangney. 2015) deriving from a social constructivist pedagogy (Wickham, Girvan and Tangney 2016). Results from various deployments of the Bridge21 model indicate that it has a positive impact on students' intrinsic motivation and their attitudes towards taking personal responsibility for their learning (Johnston, Conneely, Murchan and Tangney, 2015; Lawlor, Marshall and Tangney, 2015; Wickham, Girvan and Tangney, 2016).

2.4.2 Bridge21 Pedagogic Model

The Bridge21 model can be discussed in terms of its four main components (i) Classroom Partnership (ii) Technology-mediated (iii) Teamwork (iv) Inquiry Based Learning. Each of these components are recognised as essential for 21st Century Learning, however, their combination and systematic application is unusual in formal educational settings (Bridge21, 2015).

Classroom Partnership

The Bridge21 model transfers the control of learning from the teacher to the learner. This facilitates the characteristics of learning necessary to encourage students' intrinsic motivation and promote student responsibility (Lawlor J., Marshall K., & Tangney B. 2015). The teacher, in the Bridge21 approach, becomes a facilitator or mentor to the students. The teacher then acts, as Piaget (1973) described, as the architect of the learning experience, constructing problems that let students take the initiative to find or reconstruct the content to be learned.

Technology mediated

The role of digital technology is intrinsic to 21st century teaching and learning. Its capacity to open diverse pathways for students to construct and engage with knowledge is well documented (Sánchez, Salinas, Contreras and Meyer, 2011; Pallant & Tinker, 2004; McGarr, 2009; Bray and Tangney, B., 2016; Tangney, Bray and Oldham, 2014; Wickham, Girvan and Tangney, 2016). Technology mediated learning is a central tenant to the Bridge21 model, it is envisaged that students learn with technology rather than about technology, the technology should be shared to encourage collaboration (Bridge21, 2015).

The SAMR model (Substitution, Augmentation, Modification and Redefinition) proposed by Puentedura (2009) is a useful model that illustrates how technology can be used in learning. It divides the application of technology into two categories - enhancing or transforming learning. For transformation to occur the technology must allow for significant task redesign (modification) or allow for the creation of new or previously inconceivable tasks (redefinition) (Hamilton, E. R., Rosenberg, J. M., & Akcaoglu, M. 2016).

Teamwork

The Bridge21 model is based on a social constructivist pedagogy where learners construct their own learning rather than passively accepting knowledge delivered by other sources (Grenne, 2015). The foundation of constructivist theory is that learning is a social activity and is more effective when learners collaborate and build on each other's knowledge (Piaget et al., 1985; Vygotskii & Cole, 1978). Students are placed in mixed ability groupings to work together to achieve a common goal, this encourages students to embrace the communicative and collaborative aspects of the experience (Bauer C., Devitt., and Tangney B. 2015). The common goal in a Bridge21 context is for students to create and construct their own artefact that they can use to communicate their learning experience or outline their solutions to a problem-based activity. Research suggests that creating an artefact for others to see makes learning more effective for the student and actively engages the learners (Papert, 1980; Bruner, 1990).

The Bridge21 model incorporates Vygotsky's theory of the Zone of Proximal Development (ZDP) (Vygotskii & Cole, 1978) by recommending mixed ability groupings, where a student's learning is enhanced by interacting with a more experienced members of the group rather than learning alone.

Inquiry Based Learning

According to Conole, et al. (2008) there are four main characteristics of inquiry learning; questioning and hypothesis, adopting an evidence-based approach, synthesis and metacognition and the nature of science. These are to be adopted while also encouraging students' engagement with the focus of the lesson on the active search for knowledge or understanding to satisfy a curiosity (Harris & Rooks, 2010). A Bridge21 lesson centres around a "big problem", rather than a presentation of facts and rules (Bridge21, 2015). The 'big problem' must contain a 'hook' to capture the students' attention and motivate students to work collaboratively to address the big problem. The problems given to the students should be real-world, contextualised problems that require the students to participate in work which models the work engaged by professionals in that particular discipline. The teacher's role is to encourage students questioning, hypothesising and to set-up activities that incorporate the four characteristics outlined by Conole et al. (2008).

2.4.3 Bridge21 Activity Model

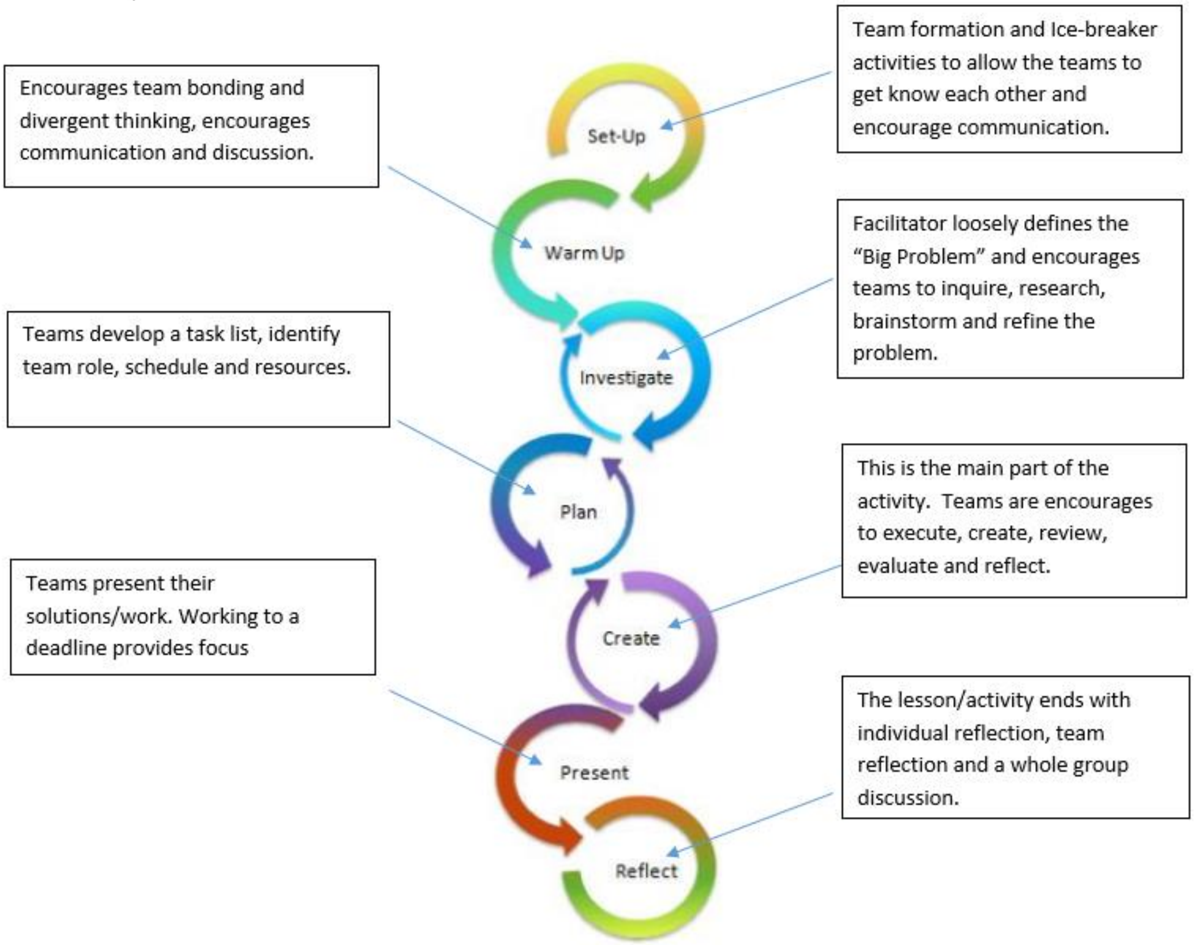


Figure 4 the Bridge21 Activity Model (Bridge21, 2015).

2.9 Summary

This chapter has outlined the challenges and opportunities that exist for teachers delivering a 21st Century Science curriculum. The key literature published to support the Junior Cycle Science specification (NCCA, 2015; NCCA, 2014; NCCA, 2013) highlights the need for an inquiry-based learning approach in order to achieve the aims of the new Junior Cycle Science specification. Instructional methodologies remain prominent in many classrooms around the world, following a didactic and transmissive pedagogy with the teacher at the centre of the learning (Lindahl, 2003; Osborne & Collins, 2000; Osborne & Dillon, 2008). This leads to students perceiving science as difficult and abstract subject, resulting in low motivation and engagement when studying science. Evidence is presented in the review that supports the use of the Bridge21 model which combines social constructivist pedagogy with inquiry based, constructionist and contextualised learning activities. Enabling learners to actively construct their own artefacts, which they share with others, leads to improved understanding and engagement. The research also provides evidence that the strategies utilised as part of the Bridge21 learning experience foster students' development of 21st Century skills.

Chapter Three: Design

3.1 Introduction

The literature review outlines the potential benefits of using the Bridge21 model to deliver a 21st Century curriculum, such as the new Junior Cycle Science specification, the potential of the model to positively impact student engagement and their development of 21st century competencies. This then leads to the research question: Does the Bridge21 model offer an effective practice when delivering aspects of the new Junior Cycle Science specification? To address the research question, a mixed methods case study (Creswell, 2003) is used. This chapter presents the design of the learning activities used for this case study and examines how they were informed by the literature review.

The first section of this chapter links the themes from the literature review to the activities design principles, implementation and anticipated outcomes. The second section provides an overview of the design of each individual learning activity, what learning outcome from the Junior Cycle Science specification it is hoped the activity will achieve or partially achieve and how each element of the Bridge21 model was incorporated into the learning activity.

3.2 Overview of the Design Table

The literature review examines the Bridge21 pedagogical model using its four main components: Classroom Partnership, Technology Mediated, Teamwork and Inquiry Based Learning. These components are recognised as essential for 21st Century learning, however, their combination and systematic application is unusual in formal educational settings (Bridge21, 2015). Therefore, it is pertinent that each of these components are incorporated in conjunction with the Bridge21 Activity Model as part of the learning experience for this research study. Each of the lessons used as part of the learning experience for this research study are presented in Chapter 4, each lesson is designed using the Bridge21 activity model. The Bridge21 model transfers the control of learning from the teacher to the learner. This facilitates the characteristics of learning necessary to encourage students' intrinsic motivation and promote student responsibility (Lawlor J., Marshall K., & Tangney B. 2015). The lessons used in this research study are student led and are presented as an IBL activity in order to engage students from the beginning of the lesson. Inquiry involves activity and skills, but the focus is on the active search for knowledge or understanding to satisfy a curiosity (Harris & Rooks, 2010). This is not achieved with the current activities presented in the Junior Certificate science. The mandatory activities outlined in that syllabus are largely prescriptive, directed by the teacher, with the outcome presented in the textbook and therefore known by the students before the experiment is concluded. The problems presented to the students in these lessons are real-world, contextualised problems that require the students to participate in work which models the work engaged by professionals in that particular discipline.

The foundation of constructivist theory is that learning is a social activity and is more effective when learners collaborate and build on each other's knowledge (Piaget et al., 1985; Vygotskii & Cole, 1978). To encourage collaboration throughout this learning experience, students are asked to work together to create an artefact that is then presented to the class. Students can use this artefact to communicate their learning experience or outline their solutions to a problem-based activity. Placing students in mixed ability groupings to work together to achieve this common goal encourages students to embrace the communicative and collaborative aspects of the experience (Bauer C., Devitt., and Tangney B. 2015). Mixed ability groupings enhance student's learning by allowing students to interact with the more experienced members of the group, rather than learning alone (Vygotskii & Cole, 1978).

The technology used throughout this learning experience is transformative (SAMR) and allows students to learn with technology rather than about technology. In each lesson the technology is shared to encourage collaboration and students create a digital artefact for others to see. This makes learning more effective for the student and actively engages the learners (Papert, 1980; Bruner, 1990). Technology used as part of this learning experience include; padlet, Microsoft power-point, Phet-Colorado simulator, Google search engine and Math App technology.

The themes from the literature review that influenced the design of the learning experience used in this study are presented in table 1.

3.2.1 Design Table

Research Reference	Key Points	Design Implications	Anticipated Outcomes
Piaget (1973)	Teacher acts as the facilitator	Emphasis on self-directed activities	Students develop 21C skills. Enhance student engagement.
(Sanchez et al., 2011) (Voogt & Roblin, 2012)	21C teaching and Learning. Diverse pathways for learners to construct and engage with knowledge. Improves engagement opportunities for experiential learning	Students create a digital artefact. Student use technology to work collaboratively.	Enhance student engagement. Students develop 21C skills. Learning is more effective.
Cognitive dissonance- (Piaget, 1929). Zone of Proximal Development, (Vygotskii & Cole, 1978)	When a learner is challenged by a disequilibrium it supports cognitive engagement particularly in problem solving	Problem based activities that challenge the learners preconceptions.	Support learner engagement and collaboration.
Constructivism – (Papert,1980) (Bruner, 1990).	learning is effective when the learner is engaged in creating personally meaningful artefacts	Allow learners to create and construct their own artefacts	Learning is more effective. Enhance student engagement.
Social Constructivist models- (Vygotskii & Cole, 1978)	Learners learn through collaboration and experimentation	Group based activities. Presentations back to the whole group.	Learners challenge each other and learn from each other. Development of 21C skills
(Healey & Roberts, 2004)	Learner centred approach Learners are	Lessons are centred around a "Big Problem".	Enhance student engagement. Students develop 21C skills.

(Conole, et al. 2008)	active Learners engage in reflective practice	Students work in groups. Students present back to whole group.	Learners develop problem solving skills.

Table 1 shows links the themes from the literature review to the activities design and anticipated outcomes.

3.3 Implementation of the Design Framework

The learning experience consisted of four lessons over an 8 week period lasting 1-1.5 hours per week. The lessons were delivered in an after school science-club style setting in the school the participants attend. Approximately 19 participants took part in the learning experience each week. Each lesson was designed using the Bridge21 Activity Model as a blueprint, the characteristics of IBL (Conole, et al., 2008) and the four main components outlined in the previous section are incorporated into the design.

- IBL - Each lesson poses a "Big Problem" for students to solve, the problems are scientifically orientated, open-ended and allows students to search for the information. Learners evaluate their explanations and reflect on their learning using reflection tasks.
- TEAMWORK - Students are arranged into teams of mixed ability groupings. This allows student's learning to be enhanced by interacting with more experienced members of the group rather than learning alone (Vygotskii & Cole, 1978).
- CLASSROOM PARTERSHIP - The teacher, in this instance the researcher, becomes a facilitator throughout the learning experience. The facilitator poses a question and a task rather than a statement encouraging students to construct their own learning and work together to achieve a common goal.
- TECHNOLOGY MEDIATED - Technology mediated learning is a central tenant to the Bridge21 model. It is envisaged that students learn with technology rather than about technology, the technology should be shared to encourage collaboration (Bridge21, 2015). The technology used in each of the following lessons allows students to collect data, work collaboratively, create a digital artefact or provide a concrete representation of an abstract concept via a simulator.

3.4 Overview of Individual Learning Activities.

3.4.1 Lesson One-Climate Change- Who are the winners and losers?

Lesson one presents the students with a social scientific problem *"Climate Change - Who are the winners and losers?"* Although icebreaker activities are advised as part of the Bridge21 activity model, they were deemed unnecessary for these learning experiences, as all participants are in second year in the same post-primary school and many attended primary school together. Students were arranged into mixed ability groupings; four teams with four students and one team with three students. Each team was asked to choose a team name and team leader. Teams were given access to one computer per group to encourage collaboration. As part of the warm-up activity students were given access to two web-based articles and asked to give their thoughts on the validity of each article at the end. The first article presented scientific explanations for climate change, the second article presents climate change as a hoax and as a result of natural phenomenon. This aspect of the lesson encourages students to critically evaluate the information they are reading. It further illustrates the need to exercise caution when sourcing information on the internet and to evaluate the reliability of information they obtain. Students are then introduced to the main activity or task: to create a presentation using the heading *Climate Change-Who are the winners and losers?* Students work collaboratively (Vygotskii & Cole, 1978) to create their presentations. The technology provides diverse pathways for learners to construct and engage with knowledge (Sanchez et al., 2011) and students are encouraged to obtain supporting evidence to answer the question and connect explanations to the evidence. Teams deliver their presentations to the group, which offers an opportunity for reflection and group discussions. In this way, learners can challenge each other and learn from each other (Vygotskii & Cole, 1978).

Figure 5 Shows samples of students work from this lesson.

Lesson One: Climate Change- Who are the winners and losers?

Learning Outcome from Junior Cycle specification activity will achieve or partially achieve.

Strand: Earth and Space Learning outcome: 7

Science Learning Outcome: Students should be able to illustrate how earth processes and human factors influence the Earth's climate, evaluate effects of climate change and initiatives that attempt to address those effects.

Strand: Nature of Science Learning outcome: 8

Science Learning Outcome: Students should be able to evaluate media-based arguments concerning Science and technology.

Bridge21 Elements	**Implementation Description**
Set up	Introduction to the lesson and team formation.
Warm up	Present students with links to two conflicting articles on climate change, allow time for students to read and discuss both web-based articles. Plenary discussion about student's thoughts.
Investigate	Present the problem; Climate Change- Who are the winners and losers? Ask each team to brainstorm approaches.
Plan	Share a success criteria/assessment rubric with the groups. Plenary discussion about possible approaches to the task and their merits. Discuss available technology. Allow the teams time to plan and divide tasks.
Create	Students create a presentation using technology of their choice.
Present	Teams present completed presentation to the group.
Reflect	All groups reflect on their presentations and approaches. Students complete an Individual Reflection Sheet.

Table 2 Illustrate how each element of the Bridge21 Activity Model is incorporated into the learning activity one, Activity Design Template.

Key Skills (Appendix C) developed through the learning activity; Working with others, Managing information & thinking, Communicating, Staying well. Being Creative, Managing myself and Being literate.

3.4.2 Lesson Two-Dolly Diving (Bray & Tangney, 2014).

Barbie Bungee Jumping was developed as an activity used to investigate a set of design principles for the creation of contextualised, collaborative and technology-mediated mathematics learning (Bray & Tangney, 2014) and was incorporated into the Bridge21 Handbook (Bridge21, 2016). The Barbie Bungee Jumping activity was modified and adapted for this study to achieve two learning outcomes from the new Junior Cycle Science specification as outlined in the Activity Template in the next section.

In this lesson, students are challenged to calculate how many rubber bands it would take to give a doll an exhilarating, but safe jump from a height (Bridge21, 2016). Students are arranged into mixed ability groupings with the same composition as lesson one, each group is given a doll, rubber bands and free software. The students must develop a working hypothesis, plan how they will investigate their hypothesis and test their hypothesis and calculations before a group competition. Teams gather data using Kinovea technology, and then find ways to represent the data using a spreadsheet. The spreadsheet will enable the generation of a function to represent the relationship between the number of bands and distance. A group discussion, to identify what constants must to be considered to ensure it is a fair competition or test, is facilitated by the teacher. Students will reflect through interactions with the teacher that acts as a facilitator for the lesson and further reflection is encouraged with peer-to peer interactions within and outside their groups. Each team will compete by dropping their doll from a height and identifying which calculations are the most accurate. All groups reflect on their calculations and present their original hypothesis and method to the group. In a final plenary, groups discuss their approaches. The facilitator leads a discussion around scientific method. Each student reflects on his/her learning using an Individual Reflection Sheet (Bridge21, 2016) (Appendix J).

Lesson Two-Dolly Diving

Learning Outcome: Students should be able to investigate patterns and relationships between physical observables.

Strand: Physical World   Learning Outcome: 3

Learning Outcome: Students should be able to recognise questions that are appropriate for scientific investigation, pose testable hypotheses, and evaluate and compare strategies for investigating hypotheses.

Strand: Nature of Science   Learning Outcome: 2

Bridge21 Elements	Description
Set up	Skip set-up and team formation, students already in teams from previous lesson.
Warm up	How many €2 coins would it take to fill this room? Facilitate a 2 minute discussion.
Investigate	Present the problem- How many bands would take to give the doll an exhilarating, but safe jump from a height? Teams brain-storm approaches.
Plan	Plenary discussion about possible approaches and their merits. Discuss available technology. Allow the teams time to plan and divide tasks.
Create	Iterative phase in which the teams gather data using a spreadsheet. The spreadsheet will enable the generation of a function to represent the relationship between bands and distance. Teams will need to calculate the distance the doll is to drop, using the clinometer App in MobiMaths.
Present	A competition in which the teams drop the dolls from the height, to see whose calculations are most accurate.
Reflect	All groups reflect on their calculations. In a final plenary, groups discuss their approaches. The facilitator leads a discussion around the mathematics.

Table 3 Illustrates how each element of the Bridge21 Activity Model is incorporated into the learning activity two, Activity Design Template.

3.4.3 Lesson Three- We are all made of atoms, but what is an atom?

Students are arranged in mixed ability groupings with five teams of three students and one team of four students. Each team engages in a short warm-up activity that encourages students to imagine the size of an atom. Students are then challenged to use a Phet-Colorado simulator, Build an Atom, to discover what an atom consists of, use information about the number of protons, neutrons, and electrons to identify an element and its position on the periodic table. A Guided Inquiry Handbook (Herzog & Moore, 2015) (Appendix K), that accompanies the lesson, scaffolds the students learning and allows them to determine whether an atom is neutral or an ion, predict the charge and determine the mass of an atom or ion.

The simulator together with the Guided Inquiry Handbook encourages students to work collaboratively, to challenge each other and to learn from one another. The simulator allows students to interact with each of the sub-atomic particles in a model of the atom and observe the effect of changing the composition of sub-atomic particles in an atom.

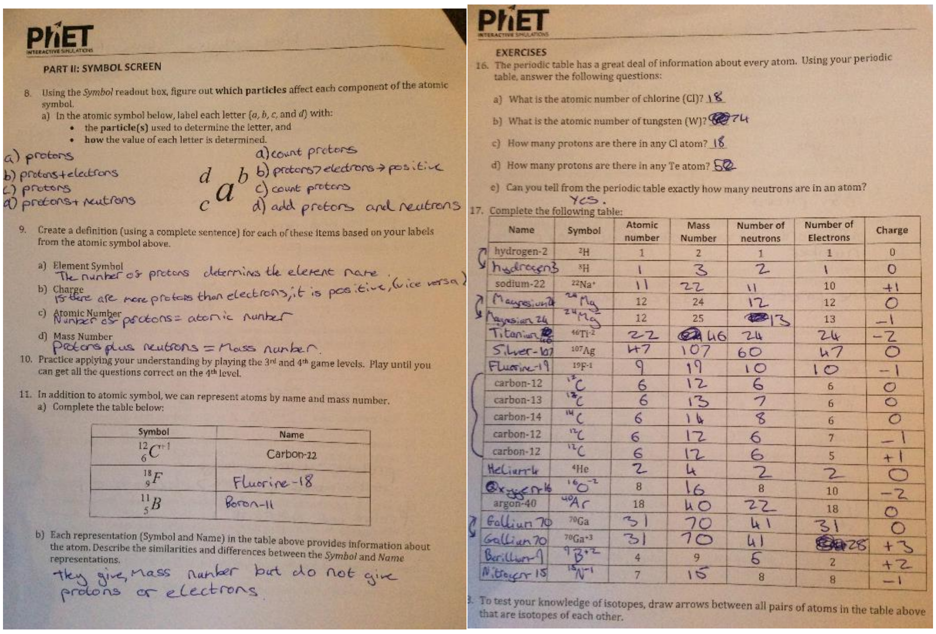


Figure 6 shows examples of student work.

Lesson Three- We are all made of atoms, but what is an atom?

Learning Outcome: Students should be able to describe and model the structure of the atom in terms of the nucleus, protons, neutrons and electrons; comparing mass and charge of protons, neutrons and electrons.

Strand: Chemical World Learning Outcome: 3

Bridge21	Description
Set up	Set-up and team formation.
Warm up	How many atoms are in a full stop?
Investigate	Guided Inquiry Activity using PhET-colorado simulator, student work in teams to complete the activity sheet (Appendix K). Each team are given an unknown atom in form of a riddle. Each team work together to solve their unique question.
Plan	Students discuss possible solutions and how best to present their solution.
Create	Students create their presentation using technology of their choice.
Present	Students present their question and answer to the group
Reflect	All groups reflect on how they solved their problem and if the group are correct lead by the facilitator.

Table 4 Illustrates how each element of the Bridge21 Activity Model is incorporated into the learning activity three, Activity Design Template.

Key Skills (Appendix C) developed through the learning activity;

Working with others, Managing information & thinking, Communicating, Staying well

Being Creative, Managing myself, Being Literate.

3.4.4 Lesson Four- Would drinking water from the river Dodder have any bad side effects?

This lesson presents students with an investigation into the water quality of their local river, the river Dodder. Participants are arranged into mixed ability groupings…….Each team is provided with a toolkit containing universal indicator, a pooter, a small jar with a lid, a light meter and a plant and animal identification key. Each team has access to a camera phone to take pictures of the area and any animal or plants that may act as indicators of good/poor water quality. Students have access to a range of test when they return to the science laboratory in school; test for dissolved solids, suspended solids and flame tests. Each team creates a presentation of their work for the group using padlet software.

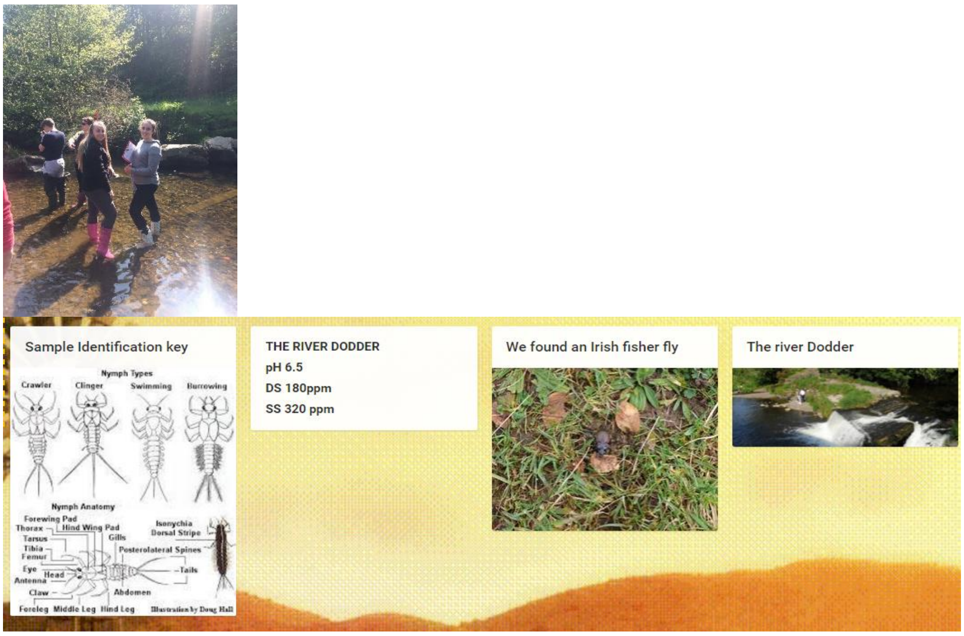


Figure 7 shows students working at the river Dodder and a sample of work.

3.4.4 Lesson four –Would drinking water from the river Dodder have any bad side effects?

Learning Outcome: Students should be able conduct a habitat study

Strand: Biological World Learning Outcome: 5

Learning Outcome: Students should be able to organise and communicate their research findings in a variety of ways fit for purpose and audience, using relevant scientific terminology and representations.

Strand: Nature of Science Learning Outcome: 7

Bridge21	Description
Set up	Skip set-up and team formation.
Warm up	Students will examine the items in their toolkit and discuss what data or information can be collected with each item.
Investigate	Students collect data and water samples from the river Dodder and photograph plant and animal species present that may help act as indicators of water quality.
Plan	Students discuss possible solutions, further tests that could be carried out and how best to present their solution.
Create	Students create their group presentation on padlet.
Present	Students share their padlet board with the other groups in the class.
Reflect	All groups reflect on their presentations and approaches. Students complete an Individual Reflection Sheet.

Table 5 Illustrates how each element of the Bridge21 Activity Model is incorporated into the learning activity four, Activity Design Template.

Key Skills (Appendix C) developed through the learning activity;

Working with others, Managing information & thinking, Communicating, Staying well, Being Creative, Managing myself, Being Literate, Being Numerate.

3.4 Summary

This chapter outlines how the learning experiences were informed by the literature review, It has also presented an overview of the design of each learning activity, what key skills and learning outcomes from the Junior Cycle Science specification it is hoped the activity will achieve or partially achieve and how each element of the Bridge21 model was incorporated into the learning activity. The learning activities were designed to address the research questions proposed in Chapter 1. The methodology used to collect data in order to answer these research questions will be outlined in the next chapter.

Chapter Four: Methodology

4.1 Introduction

The Bridge21 model was chosen as the pedagogical model for delivering aspects of the new Junior Cycle Science specification because it involves moving away from teacher centred pedagogy and is designed to release the potential of student led, inquiry based, collaborative, technology-mediated learning. These features of the model should support teachers facilitating the Key Skills and Statements of Learning set out in the new Junior Cycle Framework and science specification set out by the NCCA. This dissertation uses the Bridge21 model to develop and implement lessons, underpinned by Inquiry Based Learning strategies, to achieve certain learning outcomes on the new Junior Cycle Science specification.

A convergent mixed method case study methodology was used for the research investigation with both quantitative and qualitative data was collected. A validated attitudinal questionnaire (Friday Institute for Educational Innovation, 2012) and skills questionnaire (Ravitz, Jason, et al., 2012) was used for quantitative data capture while focus groups and observations provided rich qualitative data for triangulation. This chapter discusses the elements that informed the methodology, their inter-dependencies and the data collection and analysis methods used.

4.2 Research Questions and Data Collection

4.2.1 Research Questions

As outlined in the literature review there are many challenges that exist in science teaching today, including the declining number of students electing to study science beyond junior level and the need for students to develop 21st century skills. The purpose of this dissertation is to address the following research question-

Does the Bridge21 model offer an effective practice to deliver the new Junior Cycle Science specification?

This gives rise to additional sub-questions to be considered in this study:

- Did the learning experience have a positive or negative effect on the students' attitudes to Science?
- What aspects of the Bridge21 model positively or negatively influenced the students learning experience in Science?

4.2.2 Data collection action and its link to the research question.

Two validated questionnaires were adapted for quantitative data capture. Survey One (Appendix E) is a modified Attitudes toward STEM survey (S-STEM) which used Likert-scale items to measure students attitudes towards Science (Friday Institute for Educational Innovation, 2012). Survey Two (Appendix F) is validated 21st Century Key Skills questionnaire (Ravitz, Jason, et al., 2012) to measure students attitude toward 21st Century Key Skills.

Data collection	Sub-questions
A validated attitudinal questionnaire, (Friday Institute for Educational Innovation, 2012).	Did the learning experience have a positive or negative effect on the student's attitudes to Science?
A validated Key Skills questionnaire (Ravitz, Jason, et al., 2012). Focus group interview with interview protocol.	What aspects of the Bridge21 model positively or negatively influenced the students learning experience in Science?

Table 6 shows the data collection method and the sub-research questions that data collection should assist answering.

4.3 Research Design

A convergent parallel mixed method case study was chosen for the research methodology (Creswell, 2013). The case study methodology is appropriate as it allows for an in-depth investigation of one area of study using a relatively small sample size. Cohen, Manion and Morrison (2011, p.294) note that case studies have limited generalisability. Nevertheless they can constitute a part of a growing pool of data with multiple case studies contributing to greater generalisability. In this study the case is the use of the Bridge21 model to deliver aspects of the new Junior Cycle Science specification and the sample size is 19.

The mixed method requires both quantitative and qualitative data to be collected, analysed and congruence between the two data categories to be examined.

4.4 Implementation

The learning experiences were delivered in an after-school science club style setting over an eight week period. Participants were aged between 14-15 years old. At the time of the research students were in their second year of the post-primary school system in Ireland. A total of 19 students attended the lessons with attendance dropping to 17 on one occasion. The learning experience lasted ~ 1.5 hours each week and were delivered in the students' school. The students attend a designated disadvantaged, co-educational school in South Dublin.

Ethics approval was required from the university prior to conducting any research with participants. The University's Research Ethics Committee approved an ethics submission on 7th February 2017. Details are provided in Appendix G.

4.5 Researcher Bias

The researcher currently teaches many of the students participating in this research study, due to the nature of this relationship there is a conflict of interest. This previous knowledge of the strengths and weaknesses of the participants can unknowingly lead to research bias where information is prejudged due to preconceived ideas. A case study with research bias can lead to more complications in assessing research than that of more statistical studies (Sprinz, 2004). For this reason an anonymous questionnaire was also used in order to assess the work undertaken.

4.6 Data Collection

In order to gather qualitative data on the students' learning experience, interviews were carried out. A group interview was chosen over individual interviews because they are thought to be less intimidating for students (Cohen, Manion and Morrison, 2011, p.433). An interview protocol was decided upon, the questions were chosen to provide further explanation for initial findings following quantitative data analysis. There are many other advantages to conducting group interviews as cited by Cohen, Manion and Morrison (2011, p.432); the potential for discussion to develop, a wider range of responses, to detect how the participants support, influence, complement, agree and disagree with each other and the relationships between them. However the authors also warn of several issues the researcher needs to address; dividing your attention equally among the participants, how to handle people who are quiet or too noisy, how to handle a range of response etc. (Cohen, Manion and Morrison, 2011, p.432). A semi-structured group interview was conducted with six participants two weeks following the learning experience. The participants' selection was based on simple random sampling (Cohen, Manion and Morrison, 2011, p.153). The interview was conducted face to face, took approximately forty minutes, was audio recorded and the interview data was subsequently transcribed for analysis.

Quantitative data was collected using two surveys, both surveys were distributed pre and post the eight-week learning experience. Survey One (Appendix E). A validated survey (Fariday Institute for Educational Innovation, 2012) that measures participant's attitudes toward STEM (S-STEM) was distributed pre and post the eight-week learning experience. The survey uses the Likert-scale to measure students' attitudes towards science. Survey Two (Appendix F) is a validated 21st Century Key Skills questionnaire (Ravitz, Jason, et al., 2012) and is used to measure students' attitude toward 21st Century Key Skills. Focus groups provided rich qualitative data for triangulation.

Qualitative and quantitative data was analysed separately but will be triangulated to provide deeper insight into the research questions. This triangulation of the data has been incorporated into the data analysis procedures.

4.7 Data Analysis

Quantitative data gathered from both surveys was analysed using the Two-Sampled Chi-square test. The raw data gathered as a result of interviews presents a challenge for the researcher to produce a meaningful and trustworthy conclusion (Bassey, 1999, p.84). The data yielded in this research was analysed for nomothetic properties i.e. themes (Cohen, Mannion and Morrison, 2011, p.540). The data analysis was undertaken by making annotations in the initial interview transcript, general themes were identified and the data was analysed a second time where it was selected, coded and ordered. Themes and relevant codes sought to be identified in the data analysis; (CT) Critical thinking skills, (CO) Collaboration skills, (CM) Communication skills, (CR) Creativity and innovation skills, (S) Self-direction skills and (U) Using technology as a tool for learning.

4.8 Summary

This chapter has outlined the methodology used to address the research questions posed in this study. Through both qualitative and quantitative data collection, the researcher is attempting to assess the effect of using the Bridge21 model to deliver aspects of the new Junior Cycle Specification.

Chapter Five: Data Analysis & Findings

5.1 Introduction

This chapter presents the results of the data analysis and discusses the findings that arise. The changes between pre and post responses to survey one (Friday Institute for Educational Innovation, 2012) which measures students' attitude toward science is examined. Changes in participants' attitudes towards science and a career in science were analysed using a breakdown of positive, neutral and negative responses before and after the learning experience. Participants responses to survey two (Ravitz, Jason, et al., 2012) which measures students attitude toward 21st Century Skills, before and after the learning experience, are analysed using a two-sampled Chi Squared test (Rana & Singhal, 2015). The chapter then presents the results from direct coding of the focus group transcripts, a convergent analysis of the quantitative and qualitative data is presented and findings are considered.

5.2 Quantitative Data Analysis

5.2.1 S-STEM survey analysis

The results from the administration of survey 1 were separated into two categories;

- Confidence in science (Questions 1, 6, 8 and 9)
- Attitude towards a career in science (Questions 2, 3, 4, 5 and 7).

The S-STEM instrument uses a five point Likert scale (Strongly Disagree to Strongly Agree) to measure students' attitudes towards confidence in science and attitude towards a career in science. These items were then further refined into positive, neutral and negative responses.

5.2.2 Student confidence in Science

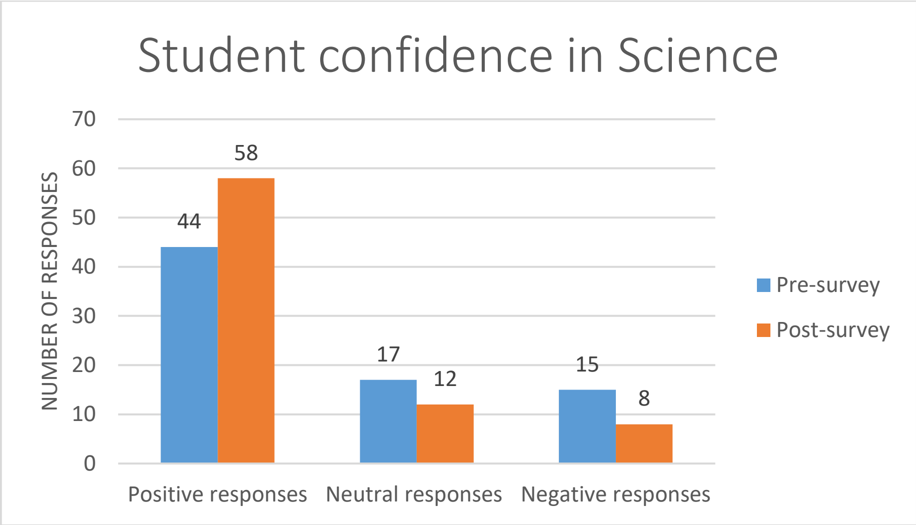


Figure 8 Displays the responses to questions relating to confidence in Science posed in survey 1

Survey one data indicated that prior to the learning experience, students' confidence in science was moderately positive, with 58% of respondents indicating a positive response (strongly agree/agree for questions 1, 6 and 9 or disagree or strongly disagree for question 8). 22% of respondents indicated a neutral response to each of the relevant questions and 20% of respondents indicated a negative response (disagree/strongly disagree for questions 1,6 and 9 and agree/strongly agree for question 8). After the learning experience was delivered, the data indicated a strong positive response to students' confidence in science. 76% of respondents positively responded to the relevant questions representing an increase of 18%. Neutral responses demonstrate a decrease of 6% (22% to 16%). Finally, negative responses declined by 11%.

5.2.3 Students attitude towards a career in Science

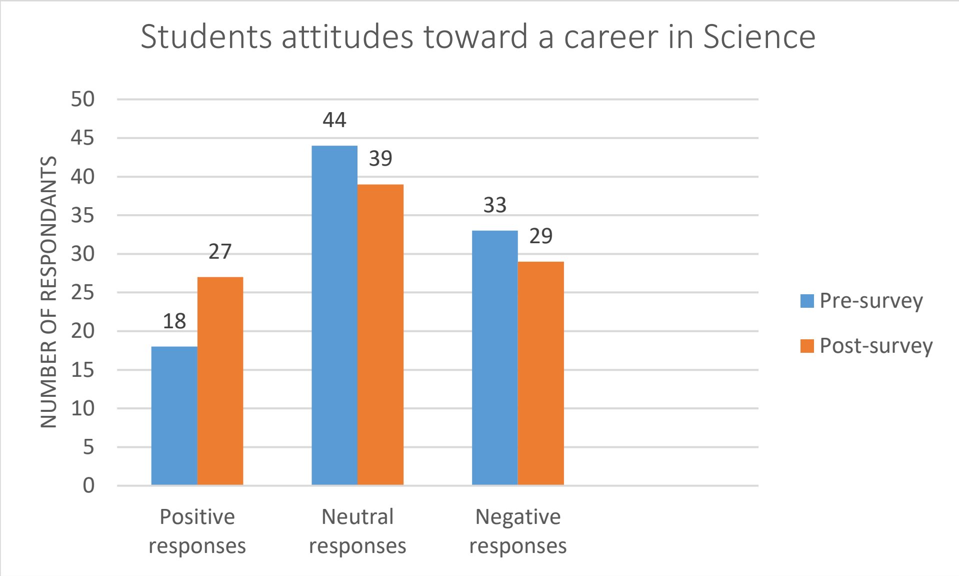


Figure 9 Displays the responses to questions in survey 1 relating to careers in Science

The second category of responses examined using survey one was students' attitude towards a career in science. The data from the pre-survey indicates low levels of interest in pursuing a career in science, with only 19% of respondents indicating a positive response (Strongly Agree/Agree). This compares to 35% of respondents indicating a negative response (Disagree/Strongly Disagree) to each of the questions relevant to attitudes on careers in science. The post-survey data showed increase of 9% in the positive response category and a marginal decrease of 3% in the negative response category, to the relevant questions, after the eight-week learning experience.

Although the pre-survey and post-survey indicated low levels of interest in pursuing a career in science, the data also indicates that the majority of respondents have a neutral level of interest in pursuing a career in science. The pre-survey showed 46% of respondents indicated a neutral response (Not Sure) to questions relevant to attitudes towards careers in science. This decreased slightly to 41% in the post-survey.

5.2.4 Analysis of Survey Two Key Skills Questionnaire

Chi-squared test

A two-sampled Chi Squared test (Rana & Singhal, 2015) was used to analyse the data from survey two, a Key Skills questionnaire. The test calculates a test statistic, the size of which reflects the probability (p-value) that the observed association between the two variables has occurred by chance. A null hypothesis is established (H_0) and assumes that there is no association between the variables, the alternative hypothesis (H_1) claims some association does exist. A p-value is generated for each skill tested and quantifies the probability that the observed data occurs by chance. The p-value allows the null hypothesis to be rejected if the p-value it is less that the alpha value set at 0.05. This provides a 95% confidence interval; this is, the normal confidence interval used in the majority of statistical analysis and is sufficient for the purposes of this research.

The null hypothesis and alternative hypothesis used for this test was:

H_0: Confidence in the identified skill is not associated with using the Bridge21 model and

H_1: Confidence in the identified skill is associated with using the Bridge21 model.

Test Statistic for Testing H_0: Distribution of outcome is independent of groups

$$\chi^2 = \Sigma \frac{(O-E)^2}{E}$$

and the critical value in a table of probabilities for the chi-square distribution is found with df=(r-1)*(c-1). For the above equation O = observed frequency, E=expected frequency in each of the response categories in each group, r = the number of rows in the two-way table and c = the number of columns in the two-way table.

Expected Value

The expected value or mean (Hammitt & Shlyakhter, 1999) of X, where X is a discrete random variable, is a weighted average of the possible values that X can take, each value being weighted according to the probability of that event occurring. The data obtained from survey two (Appendix F) was used to calculate weighted averages of confidence for before and after the learning experience was delivered. A 'confidence scale' was created i.e. Not at all confidence = 0, Not very confident = 1, Neutral = 2, etc. To obtain the weighted average the product of the confidence scale was summed by the frequency of the confidences, and then divided by the sum of the frequencies. For example, looking at the data on spreadsheet 2 (Appendix H) for critical thinking before the learning experience, the weighted average = (24*0 + 38*1 + 25*2 + 14*3 + 12*4) / (24 + 38 + 25 + 14 + 12) = 1.57. This calculation produces the Expected Value or 'mean confidence' of the 'before' graph. From the confidence scale, a value of 1.57 is somewhere between 'Not Very Confident' and 'Neutral'. Doing the same for the data obtained after the learning experience was delivered a value of 2.29 is obtained, on the scale somewhere between 'Neutral' and 'Confident'.

21st Century Competence	p-value	H_0	confidence before	confidence after	change in confidence
Critical Thinking Skills	0.0004	reject	1.57	2.29	0.72
Communication Skills	0.0009	reject	1.84	2.53	0.68
Creativity and Innovation	0.0005	reject	2.13	2.72	0.59
Self Direction	0.0012	reject	1.91	2.52	0.61
Collaboration Skills	0.0015	reject	2.19	2.75	0.56
Using Technology	0.0013	reject	1.91	2.51	0.6

Table 7 summarises the p-value and expected value or mean confidence obtained for each 21st Century Competency examined using survey two.

Statistical Power

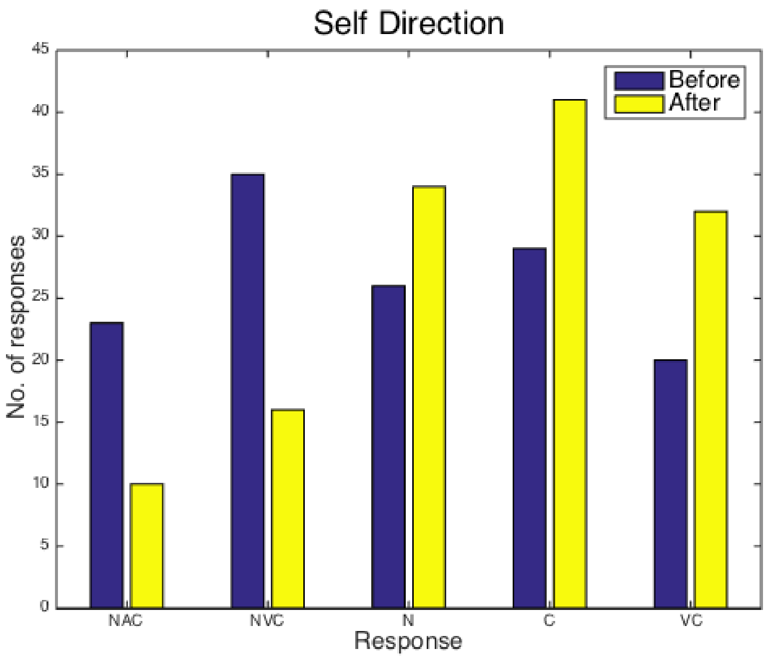
The power of a statistical test of a null hypothesises if the probability that the H_0 will be rejected when it is false i.e. the probability the result obtained is statistically significant. Statistical Power of this research data for experiments with 5, 6, 7 & 8 questions respectively are: 0.9854, 0.9957, 0.9988, 0.9997. These are all high statistical powers with 98% to 99% certainty in the ability to reject a false null hypothesis given the sample sizes of (19*5=95, 19*6=114, 19*7=133, 19*8=152) at a critical significance threshold of alpha=0.05 and using (5-1) =4 degrees of freedom.

Statistical Test	Sample Size	Power	Degrees of Freedom	Effect size	Significance Level
Chi-Square	95.000	0.9854	4	0.5	0.05
Chi-Square	114.000	0.9957	4	0.5	0.05
Chi-Square	133.000	0.9988	4	0.5	0.05
Chi-Square	152.000	0.9997	4	0.5	0.05

Table 8 Shows the results for the statistical power of each sample size used in survey two.

5.2.4 Results of the Two-Sample Chi-Squared test for 21st Century Key Skills.

The bar charts presented in figs 5.3-5.8 illustrates the relationship between participants' confidence in a 21st Century Key Skills before and after the learning experience. A clear shift in the pattern of responses before and after the learning experience is visible in each chart.



KEY

NAC = not at all confident

NVC =not very confident

N= neutral

C= confident

VC= very confident

Figure 10 illustrates student's confidence in their self-direction skills before and after the learning experience.

The p-value generated for this test was 0.0012, which is less than 0.05 allows the null hypothesis to be rejected and accept H_1 for this test; Confidence in self-direction skills is associated with using the Bridge21 model. The statistical power for this test was calculated at 0.9988 i.e. there is a 99% certainty in the ability to reject a false null hypothesis given the sample size of 133 for this test.

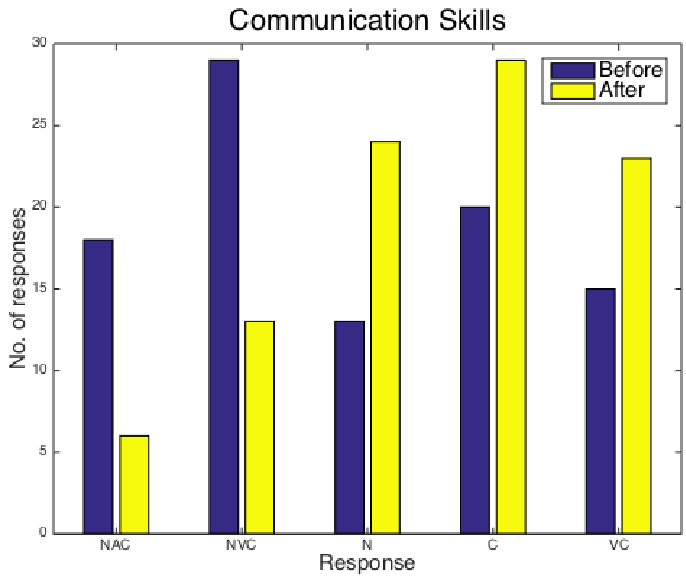


Figure 11 illustrates student's confidence in their communication skills before and after the learning experience.

The p-value generated for this test was 0.0009, which is less than 0.05 allows the null hypothesis to be rejected and accept H_1 for this test; Confidence in communication skills is associated with using the Bridge21 model. The statistical power for this test was calculated at 0.9854 i.e. there is a 98% certainty in the ability to reject a false null hypothesis given the sample size of 95 for this test.

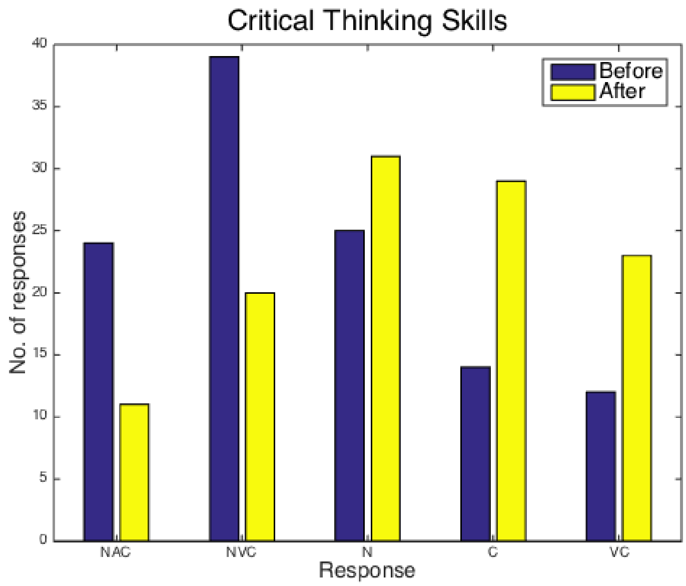


Table 9 illustrates student's confidence in their critical thinking skills before and after the learning experience.

The p-value generated for this test was 0.0004, which is less than 0.05 allows the null hypothesis to be rejected and accept H_1 for this test; Confidence in critical thinking skills is associated with using the Bridge21 model. The statistical power for this test was calculated at 0.9957 i.e. there is a 99% certainty in the ability to reject a false null hypothesis given the sample size of 114 for this test.

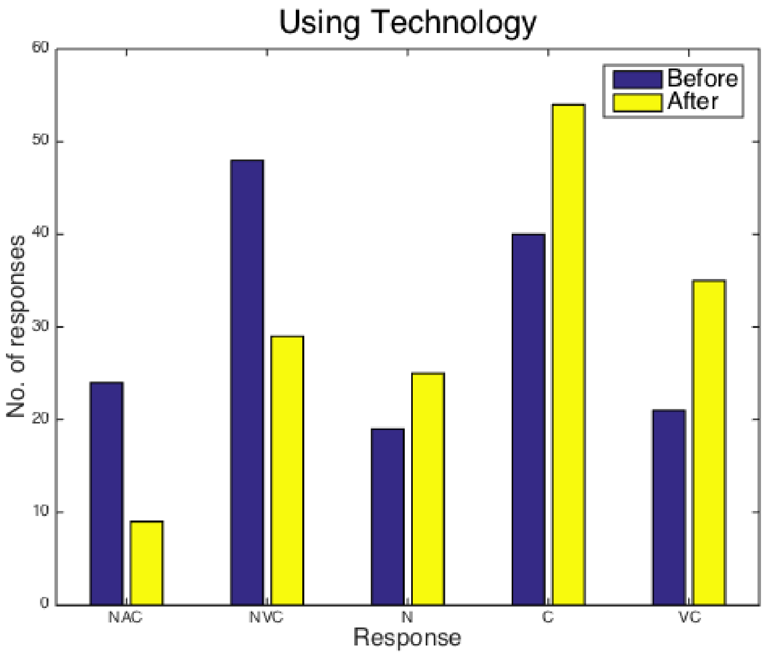


Figure 12 illustrates student's confidence in their technology skills before and after the learning experience.

The p-value generated for this test was 0.0013, which is less than 0.05 allows the null hypothesis to be rejected and accept H_1 for this test; Confidence in using technology is associated with using the Bridge21 model. The statistical power for this test was calculated at 0.9997 i.e. there is a 98% certainty in the ability to reject a false null hypothesis given the sample size of 152 for this test.

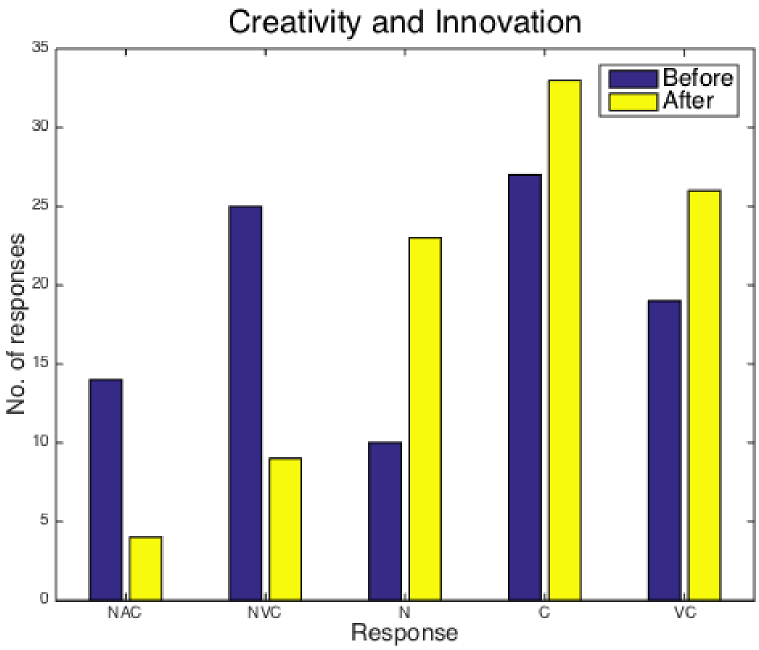


Figure 13 illustrates student's confidence in their creativity and innovation skills before and after the learning experience.

The p-value generated for this test was 0.0005, which is less than 0.05 allowing the null hypothesis to be rejected and accept H_1 for this test; Confidence in creativity and innovation skills is associated with using the Bridge21 model. The change in confidence, presented in table 5.1, is lower for creativity skills compared to other skills. It would appear the reason for this is that confidence in this skill was high (greater than 2) before the learning experience therefore the same shift from NVC to N-C is not observed. The statistical power for this test was calculated at 0.9854 i.e. there is a 98% certainty in the ability to reject a false null hypothesis given the sample size of 95 for this test.

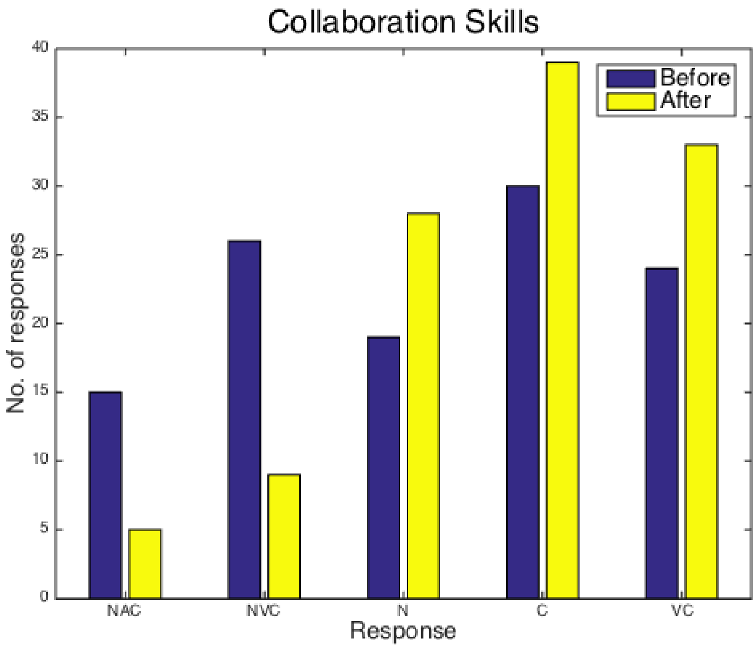


Table 10 illustrates student's confidence in their collaboration skills before and after the learning experience.

The p-value generated for this test was 0.0015, which is less than 0.05 allowing the null hypothesis to be rejected and accept H_1 for this test; Confidence in collaboration skills is associated with using the Bridge21 model. Similar to the latter result change in confidence, presented in table 5.1, is lower for collaboration skills compared to other skills. It would appear the reason for this is that confidence in this skill was high (greater than 2) before the learning experience therefore the same shift from NVC to N-C is not observed. The statistical power for this test was calculated at 0.9957 i.e. there is a 98% certainty in the ability to reject a false null hypothesis given the sample size of 114 for this test.

5.3 Qualitative Data Analysis

A mixed methods research design was chosen for this research investigation with importance being placed on both the collection of qualitative data and quantitative data. One focus group session was held at the end of the eight-week learning experience with 30 minutes of discussion recorded. An interview protocol (Appendix L) was prepared to guide the group interview, questions were identified following initial quantitative data analysis in order to provide further insight to participants responses. Participants were allowed to express opinions freely and the researcher followed up with clarification questions to provide further insight.

The raw data gathered (Appendix I) as a result of interviews presents a challenge for the researcher to produce a meaningful and trustworthy conclusion (Bassey, 1999, p.84). The data yielded in this research was analysed for nomothetic properties i.e. themes (Cohen, Mannion and Morrison, 2011, p.540). The data analysis was undertaken by making annotations in the initial interview transcript and identifying general themes i.e. open coding (Appendix J). The data was then analysed a second time to identify these themes using direct coding process, the results of which are presented in table 5.3.

A statement by a student such as,

> *"you learn more when you're thinking for yourself (SD) and its more interesting (PE) figuring it out (CT) with your friends (CO) or for yourself instead of being told the next step you can decide with the group what you're going to try next, it's more exciting that way"*

was coded SD (self-directed learning), PE (positive engagement), CT (critical thinking) and CO (collaboration).

A statement by a student such as,

> *"I didn't like getting up and presenting stuff"*

was coded NE (negative engagement).

Theme	Code
Collaboration	CO
Self-Directed learning	SD
Critical Thinking	CT
Using Technology	T
Positive Engagement	PE
Negative Engagement	NE

Table 11 Emerging themes from focus group interviews

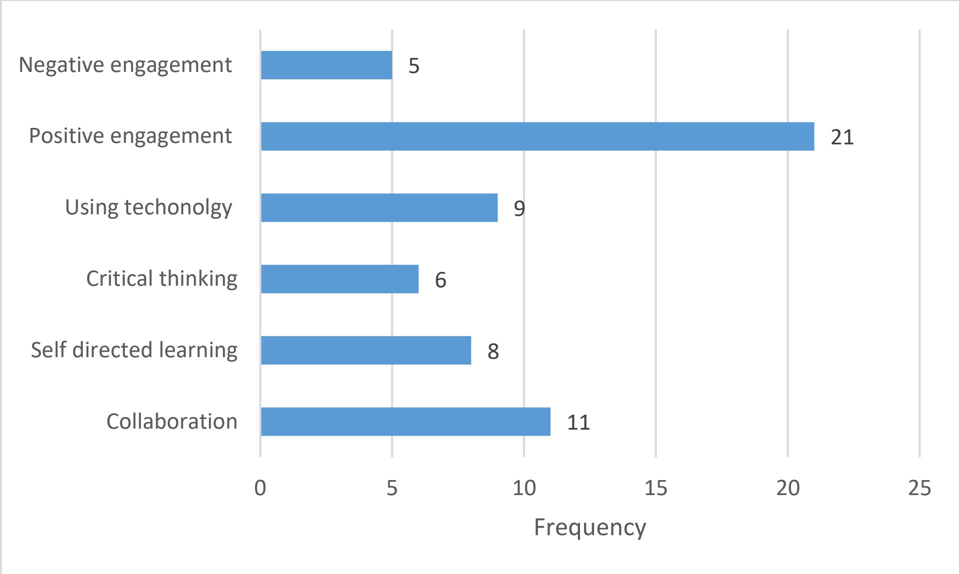


Figure 14 Graph showing the frequencies resulting from the direct coding of the focus group transcripts.

Respondents had very strong feelings and insight to provide on their experience of the learning intervention. Many positive comments (f=21) were recorded in relation to various aspects of the learning experience, predominantly collaboration and the opportunities for self-directed learning. Students articulated negative comments in relation to their experience during science class, often describing it as prescriptive and boring with a lack of self-direction. In contrast, students felt during the learning intervention that they were challenged to work collaboratively in order to solve engaging problem. For example, one student stated the following,

> *"Yeah but this was different, in experiments you tell us what to do next but we had to direct this ourselves, in those lessons [learning intervention] even when we weren't doing experiments".*

And two other students stated:

> *"You usually explain things to us and in those classes we had to do it for ourselves"*

> *"the stuff we were doing wasn't like a yes or no or right and wrong they were more like a puzzle and you had to work together to solve it I really liked that you know the answer wasn't just in the book"*

Technology also featured as an emerging theme throughout the focus group interview. Respondents referred to the use of technology as a positive contributor to their engagement. One student commented that,

> *"it was fun using the computer, it was easier to picture it because the computer gave a picture of like an atom, you can't picture it when you learning from the book as easy".*

Negative experiences (f=5) of the learning experience were all focused around a dislike students had for presenting to their peers, however each of the students participating in the focus group acknowledged the benefit in acquiring and developing their presentation skills.

5.4 Findings

The following section presents the findings from the quantitative and qualitative data analysis described earlier. Congruence between both sets of data is examined to support confirmation of findings from either source.

5.4.1 Changes in students attitudes towards Science after the learning experience

58% of students that participated in this research study responded positively to the questions in survey 1 relating to their attitudes towards science before the learning experience. This supports the research presented in the literature review that describes a poor level of engagement with the subject. After the learning experience was delivered, 76% of responses indicated a positive attitude towards science. When examining this topic during the focus group interview students indicated that a lack of opportunity to engage in collaboration and self-directed learning during science class negatively influenced their attitudes towards the subject. Students voiced a strong preference for directing their own learning and working collaboratively to solve complex problems, allowing for this type of learning increased students' engagement with science. This is further demonstrated by the increase in positive responses following the learning experience.

The second part of survey 1 examined students' attitude regarding a career in science. Respondents indicated very low levels of interest, with only 19% of responses indicating a positive reaction to a career in science. This number of positive responses increased to 28% following the learning experience. The majority of participants indicated a neutral response, before and after the learning experience, to questions relating to a career in science. This was area was also touched upon in the focus group interviews. Here participants were not strongly opposed to pursuing a career in science but instead appeared confused as to what a career in science would entail and how the learning experience related to a career in science. Students also failed to make the connection between what they learned as part of the learning experience and how it related to their own lives. Student comments this view during the focus group interview included:

> *"I just don't think it's of any use to me, like I don't know what working in science means, what would you work at? What job would you have?"*
>
> *"It's not useful in my day to day life, I don't ever really use anything we learn and you have to be really smart to make to big discovery."*

5.4.2 What aspects of the Bridge21 model positively or negatively influenced the students learning experience in Science?

The Bridge21 model is discussed in the literature review in terms of its four main components; (i) Classroom Partnership (ii) Technology-mediated (iii) Teamwork (iv) Inquiry Based Learning. Participants in this research study identified elements from each of these components as contributing to their positive experience during the science lessons delivered in this study.

Classroom Partnership

The opportunity for students to direct their own learning rather then follow the directions of a teacher was a prominent theme throughout the focus group interviews. Students articulated a clear preference for taking responsibility for their own learning and described the activities as more *"exciting"* and *"fun"* when given that opportunity. The quantitative data supports the evidence that students engaged in self-directed learning as the results showed a statistical significant improvement in student's confidence in this skill after the learning experience.

Technology Mediated

Using technology emerged as a positive theme during the focus group interviews. Participants enjoyed leaving the usual environment of the science lab and working in the computer room, using computers or their mobile phones as tools to engage with knowledge. Although the frequency technology was referred to during the focus group interviews was lower than other aspects of the learning experience, it was the technology that enabled many of the aspects that engaged students. Such as collaboration and self-directed learning which were two dominant themes throughout the focus group interviews. Students' confidence in using technology increased after the learning experience delivered in this study, as seen in the results of survey two.

Teamwork

Teamwork or collaboration was identified by participants as strong factor in the enjoyment and motivation throughout the learning experience. Allowing students the opportunity to construct their own learning in a social activity positively influenced students throughout the learning experience. Students further identified the opportunity for enhancement of their learning by interacting with other members of the group or class rather than learning alone. A participant's confidence in collaboration and communication skills increased after the learning experience as demonstrated by the data analysis on survey two.

Inquiry Based Learning

The problems presented to participants in this research study were open ended and designed to capture the students' attention. As one student remarked *"there was no yes or no answer, or right or wrong answer"*. Using an inquiry approach allowed participants to take ownership of their own learning, which they identified in focus group interview as a motivating factor throughout the experience. An inquiry approach promoted collaboration and students motivated and supported each other to work through the various problems.

5.5 Summary

Chapter five presents the data analysis and findings of the research work undertaken in this study. The data analysis has led to findings that support the use of a social constructivist pedagogy with an inquiry based approach such as Bridge21. The use of the Bridge21 model to deliver the learning experience used in this research study has positively impacted students engagement in science and statistically significant impact on students confidence in the Key Skills examined; collaboration, using technology, critical thinking, creativity and innovation and self-direction.

Chapter Six: Conclusion

6.1 Introduction

This chapter presents the conclusions reached as a result of the data analysis and findings reached in chapter five. Statistically significant improvements have been observed in each of the 21st Century Key Skills surveyed. This chapter considers the potential limitations of the research strategies implemented as part of this research. Areas of further research and investigation are suggested.

6.2 Findings reached in relation to research questions identified

Does the Bridge21 model offer an effective practice to deliver the new Junior Cycle Science specification?

This gives rise to additional sub-questions to be considered in this study:

- Did the learning experience have a positive or negative effect on the students' attitudes to Science?
- What aspects of the Bridge21 model positively or negatively influenced the students' learning experience in Science?

6.2.1 Did the learning experience have a positive of negative effect on the students' attitudes toward Science?

The data gathered from survey one indicates a positive shift in students' attitude toward science after the learning experience. This is evidenced in positive responses to the questions pertaining to attitudes towards science increasing by 18% following the learning experience. Interview analysis further indicates that the students' experience throughout the lessons delivered as part of this research study influenced their engagement toward science as a subject. All students indicated that they would be happy to study science as a subject to leaving certificate level. Students further indicated a preference for their teacher to deliver science lessons in class as in the learning experience delivered for this research study. Some students articulated negative comments in relation to their experience during timetabled science classes and contrasted that experience to the lessons used in this research study. This supports the view taken in the literature review that current practices such as didactic teaching styles and prescriptive experiments are not engaging students in science.

When students were directly asked why they enjoyed these science lessons, they clearly associated their positive engagement elements of the Bridge21 model. The Bridge21 model was the blueprint for delivering each of the science lessons used in this study, and designing the lessons in this way positively impacted students' engagement with science. Students specifically acknowledge the opportunity to self-direct their own learning, engage in inquiry orientated activities and work collaboratively with their peers.

The second element of survey one examines students attitudes' toward a career in science. The data gathered indicates low levels of interest in pursuing a career in science before and after the learning experience. The data also indicates that the majority of respondents have a neutral level of interest in pursuing a career in science. When this issue was explored during focus group interviews, students failed to make a connection between what they were learning and doing in science lessons and its application to roles in the workforce.

When discussing one of the lessons delivered in the learning experience one student commented:

> *"we could go off with our group and try and solve things ourselves and it was like we were like real science people".*

The positive shift in attitudes towards science coupled with students' positive engagement with the learning experience indicate that lessons which incorporate modelling the work of a scientist may enable students to make the connection between these activities and working in science.

6.2.2 What aspects of the Bridge21 model positively or negatively influenced the students learning experience in science?

The data analysis confirms students' confidence increased after the learning experience with regard to the six key skills examined in survey two: critical thinking skills, communication skills, self-direction skills, using technology, collaboration skills and creativity & innovation skills. The evidence gathered in survey two therefore confirms that students engaged with aspects of the model that promoted these skills. Evidence gathered during the focus group interview indicated that providing the opportunity for students to develop these skills positively influenced their engagement with science. The theme that emerged strongest from the focus group interviews was students' enthusiasm to engage in collaborative and self-directed learning. Participants further identified the opportunities provided by the tasks or problems presented and the technology incorporated into the lessons. They also identified the technology as contributing to their engagement in the science lessons, with students describing using technology as *"fun"* and *"useful"*. The technology incorporated as part of the learning experience provided the flexibility for differentiated learning, encouraged collaboration between participants and the facilitated the benefits of a social constructivist approach.

Using the Bridge21 model to achieve certain learning outcomes from the Junior Cycle Science specification enabled students to achieve the learning outcome and simultaneously develop the Key Skills identified as necessary by the Junior Cycle Framework. Achieving this result using traditional teaching methods would prove difficult. This supports the assertion made in the study that a pedagogy such as the Bridge21 model is required to successfully deliver Junior Cycle Science.

The current Junior Certificate mandatory experiments do not provide many opportunities for Inquiry Based Learning. Many of the mandatory practical activities are prescriptive, resulting in time constraints for teachers who wish to allow their students to engage in Inquiry Based Learning. The learning outcomes described in the new Junior Cycle specification provide the scope for Inquiry Based Learning, however this is best achieved using a social constructivist model to set up activities such as those used in this study.

An important point emphasised in the literature relating to the Junior Cycle Science specification is the importance of inquiry-based teaching and learning when achieving the intended learning outcomes (NCCA 2013 and NCCA, 2015). The consultation report (NCCA, 2014) highlighted that an inquiry-based approach would be necessary to achieve the aims of the new Junior Cycle Science specification. Using the Bridge21 model to implement a 21st Century curriculum, such as the new Junior Cycle Science, would positively impact students' engagement with science and foster the development of 21st century competencies.

6.3 Limitations of the Work

- **Focus Group**

  The focus group interview was held one week after the learning experience was complete. If the interview was conducted immediately after the learning experience it may have yielded fresh opinions from participants regarding the learning experience. One focus group interview did not allow time for meaningful discussion on each of the individual learning experiences. An interview should have held after each lesson to provide richer qualitative data on individual lessons. Due to time constraints this was not possible.

- **Data collection**

  On reviewing the focus group transcripts there were many occasions that a follow-up question or clarification question should have been asked. This was due to the inexperience of the researcher at hosting focus groups. Additional questions should have been asked in order to clarify and explore fully the points raised by participants.

- **Data Analysis**

  Anonymous questionnaire were used in order to offset any implications from conflict of interest due to the researcher teaching the participants on a day to day basis. A coding mechanism should have been implemented by the researcher in order to compare each participants responses before and after the learning experience.

- **Timing of Focus Groups**

  Due to time constraints one focus group interview was conducted at the end of the eight-week learning experience, this prevented in depth analysis of the impact of each individual learning experience.

- **Voluntary Nature of the Participants**

  The participants who took part in this research study were self-selecting and gave freely of their time after school. These participants may be positively biased in their attitudes towards science at the outset.

6.4 Recommendations for Future Work

These lessons designed using the Bridge21 model were delivered as part of an out of school activity. Further research is required into how this model can be incorporated into a school environment where short class times prevail e.g. 40 minutes minimum and 80 minutes maximum.

The new Junior Cycle Science specification presents learning outcomes that are best achieved using an IBL model. This type of approach would be supported by using an instructional design model such as Bridge21. Examining how this could be achieved in schools would be of benefit to teachers and students.

6.4 Summary

The purpose of this case study was to investigate the use of the Bridge21 model to deliver aspects of the new Junior Cycle science specification. The data analysis and findings presented in chapter five strongly support the use of a social constructivist, inquiry based pedagogy, such as Bridge21, to deliver the new Junior Cycle specification. Findings indicate that the use of the Bridge21 model positively influenced student's engagement with science and promoted student's intrinsic motivation. Aspects of the model that positively influenced students learning experience in science included; inquiry based approach, opportunity for collaboration, teamwork and self-directed learning and using technology.

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Appendices

Appendix A

Eight Principles of Learning.

Appendix B

Statements of Learning

	The student
1	communicates effectively using a variety of means in a range of contexts in L1*
2	listens, speaks, reads and writes in L2* and one other language at a level of proficiency that is appropriate to her or his ability
3	creates, appreciates and critically interprets a wide range of texts
4	creates and presents artistic works and appreciates the process and skills involved
5	has an awareness of personal values and an understanding of the process of moral decision making
6	appreciates and respects how diverse values, beliefs and traditions have contributed to the communities and culture in which she/he lives
7	values what it means to be an active citizen, with rights and responsibilities in local and wider contexts
8	values local, national and international heritage, understands the importance of the relationship between past and current events and the forces that drive change
9	understands the origins and impacts of social, economic, and environmental aspects of the world around her/him
10	has the awareness, knowledge, skills, values and motivation to live sustainably
11	takes action to safeguard and promote her/his wellbeing and that of others
12	is a confident and competent participant in physical activity and is motivated to be physically active
13	understands the importance of food and diet in making healthy lifestyle choices
14	makes informed financial decisions and develops good consumer skills
15	recognises the potential uses of mathematical knowledge, skills and understanding in all areas of learning
16	describes, illustrates, interprets, predicts and explains patterns and relationships
17	devises and evaluates strategies for investigating and solving problems using mathematical knowledge, reasoning and skills
18	observes and evaluates empirical events and processes and draws valid deductions and conclusions
19	values the role and contribution of science and technology to society, and their personal, social and global importance
20	uses appropriate technologies in meeting a design challenge
21	applies practical skills as she/he develop models and products using a variety of materials and technologies
22	takes initiative, is innovative and develops entrepreneurial skills
23	brings an idea from conception to realisation
24	uses technology and digital media tools to learn, communicate, work and think collaboratively and creatively in a responsible and ethical manner

*L1 is the language medium of the school (Irish in Irish-medium schools). L2 is the second language (English in Irish-medium schools).

CREAT DON TSRAITH SHÓISEARACH

Nuáil agus Sainiúlacht
Smaointe faoi Shraith Shóisearach nua

NCCA
An Chomhairle Náisiúnta Curaclaim agus Measúnachta
National Council for Curriculum and Assessment

Ráitis Foghlama

1	déanann an scoláire cumarsáid éifeachtach le roinnt meán agus i réimse comhthéacsanna sa T1*
2	déanann an scoláire éisteacht, labhairt agus léitheoireacht sa T2* agus i dteanga amháin eile ag leibhéal inniúlachta atá ag teacht lena c(h)umas féin
3	déanann an scoláire réimse leathan téacsanna a chruthú, a mheasúnú agus a léirmhíniú
4	cruthaíonn agus cuireann an scoláire i láthair saothair ealaíne agus tuigeann sé/sí an próiseas agus na scileanna atá i gceist
5	tá feasacht ag an scoláire ar luachanna pearsanta agus tuiscint ar phróiseas chun cinntí morálta a dhéanamh
6	tá meas ag an scoláire ar an mbealach ina gcuireann luachanna, creidimh agus traidisiúin éagsúla leis na pobail agus leis an gcultúr ina gcónaíonn sí/sé
7	tá meas ag an scoláire ar a bhfuil i gceist le bheith ina s(h)aoránach gníomhach, le cearta agus dualgais i gcomhthéacsanna áitiúla agus i gcomhthéacsanna níos leithne
8	tá meas ag an scoláire ar an oidhreacht áitiúil, náisiúnta agus idirnáisiúnta agus tuigeann sé/sí an tábhacht atá ag an ngaol idir eachtraí atá thart agus eachtraí reatha, agus na fórsaí is cúis le hathrú
9	tuigeann an scoláire bunús agus tionchair ghnéithe sóisialta, eacnamaíocha agus comhshaoil an domhain mórthimpeall uirthi/air
10	tá an fheasacht, an t-eolas, na scileanna, na luachanna agus an t-inspreagadh ag an scoláire le maireachtáil go hinbhuanaithe
11	déanann an scoláire gníomh chun a leas féin agus leas dhaoine eile a chosaint agus a chothú
12	tá an scoláire ina rannpháirtí muiníneach agus cumasach sa ghníomhaíocht fhisiciúil agus inspreagadh inti/ann le bheith gníomhach go fisiciúil
13	tuigeann an scoláire tábhacht an bhia agus an chothaithe i leith cinntí sláintiúla a dhéanamh
14	déanann an scoláire cinntí eolasacha airgeadais agus forbraíonn sí/sé scileanna maithe tomhaltacha
15	aithníonn an scoláire an úsáid is féidir a bhaint as eolas, scileanna agus tuiscint mhatamaiticiúil i réimsí uile na foghlama
16	déanann an scoláire cur síos ar phatrúin agus ar choibhneasa agus déanann sí/sé iad a léiriú, a léirmhíniú, a thuar agus a mhíniú
17	déanann an scoláire straitéisí a cheapadh agus a mheas chun fadhbanna a fhiosrú agus a réiteach ag baint úsáide as eolas, réasúnaíocht agus scileanna matamaiticiúla
18	déanann an scoláire breathnú agus measúnú ar eachtraí agus próisis eimpíreacha agus tarraingíonn tátail agus cinntí astu
19	tá luach ag an scoláire ar ról agus cion na heolaíochta agus na teicneolaíochta i leith na sochaí, agus an tábhacht phearsanta, shóisialta agus dhomhanda atá leo
20	baineann an scoláire úsáid as teicneolaíochtaí cuí chun dul i ngleic le dúshlán deartha
21	cuireann an scoláire scileanna praiticiúla i bhfeidhm de réir mar a fhorbraíonn sí/sé múnlaí agus táirgí ag baint úsáide as ábhair agus as teicneolaíochtaí éagsúla
22	léiríonn an scoláire tionscnaíocht, tá sí/sé nuálach agus forbraíonn sí/sé scileanna fiontraíochta
23	tógann an scoláire smaoineamh ar aghaidh ó cheapadh go réadú
24	úsáideann an scoláire an teicneolaíocht agus uirlisí na meán digiteacha chun foghlaim, chun cumarsáid a dhéanamh, chun obair agus chun smaoineamh go comhoibríoch agus go cruthaitheach ar bhealach freagrach agus eiticiúil

* Is í T1 an teanga ina bhfeidhmíonn an scoil .i. Béarla i scoileanna a fheidhmíonn trí mheán an Bhéarla agus Gaeilge i scoileanna a fheidhmíonn trí mheán na Gaeilge. Is í T2 dara teanga na scoile .i. Gaeilge i scoileanna a fheidhmíonn trí mheán an Bhéarla agus Béarla i scoileanna a fheidhmíonn trí mheán na Gaeilge.

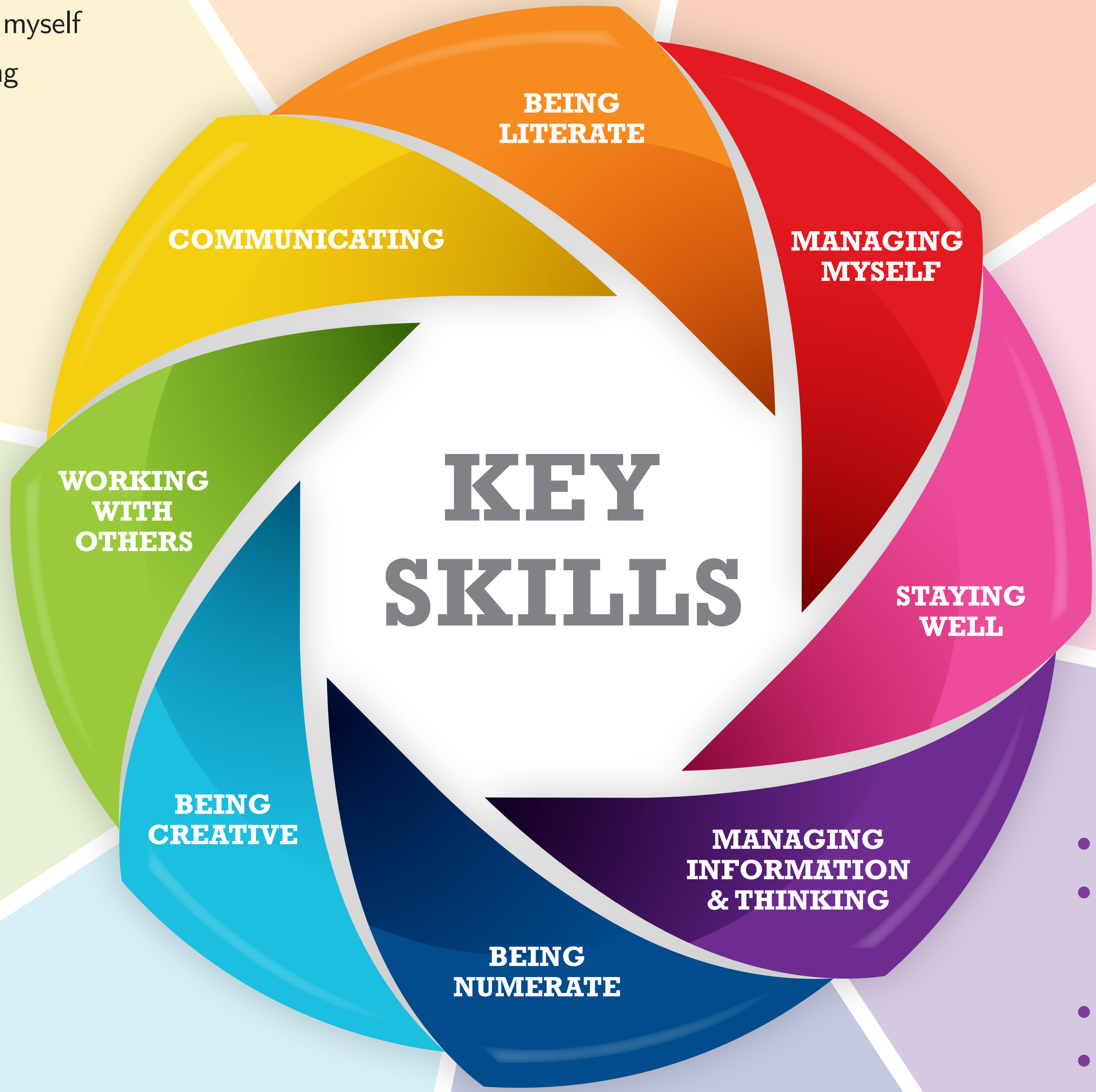
Appendix C

Key Skills of Junior Cycle

- Developing my understanding and enjoyment of words and language
- Reading for enjoyment and with critical understanding
- Writing for different purposes
- Expressing ideas clearly and accurately
- Developing my spoken language
- Exploring and creating a variety of texts, including multi-modal texts.

- Knowing myself
- Making considered decisions
- Setting and achieving personal goals
- Being able to reflect on my own learning
- Using digital technology to manage myself and my learning

- Using language
- Using number
- Listening and expressing myself
- Performing and presenting
- Discussing and debating
- Using digital technology to communicate



- Being healthy and physically active
- Being social
- Being safe
- Being spiritual
- Being confident
- Being positive about learning
- Being responsible, safe and ethical in using digital technology

- Developing good relationships and dealing with conflict
- Co-operating
- Respecting difference
- Contributing to making the world a better place
- Learning with others
- Working with others through digital technology

- Being curious
- Gathering, recording, organising and evaluating information and data
- Thinking creatively and critically
- Reflecting on and evaluating my learning
- Using digital technology to access, manage and share content

- Imagining
- Exploring options and alternatives
- Implementing ideas and taking action
- Learning creatively
- Stimulating creativity using digital technology

- Expressing ideas mathematically
- Estimating, predicting and calculating
- Developing a positive disposition towards investigating, reasoning and problem-solving
- Seeing patterns, trends and relationships
- Gathering, interpreting and representing data
- Using digital technology to develop numeracy skills and understanding

AN ROINN OIDEACHAIS AGUS SCILEANNA | DEPARTMENT OF EDUCATION AND SKILLS

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National Council for Curriculum and Assessment

www.juniorcycle.ie

Appendix D

An tSraith Shóisearach do Mhúinteoirí

Junior CYCLE for teachers

Junior Cycle Science Learning Outcomes

Strands

Nature of Science

Understanding About Science

1. Students should be able to appreciate how scientists work and how scientific ideas are modified over time

Investigating in Science

2. Students should be able to recognise questions that are appropriate for scientific investigation, pose testable hypotheses, and evaluate and compare strategies for investigating hypotheses
3. Students should be able to design, plan and conduct investigations; explain how reliability, accuracy, precision, fairness, safety, ethics, and selection of suitable equipment have been considered
4. Students should be able to produce and select data (qualitatively/quantitatively), critically analyse data to identify patterns and relationships, identify anomalous observations, draw and justify conclusions
5. Students should be able to review and reflect on the skills and thinking used in carrying out investigations, and apply their learning and skills to solving problems in unfamiliar contexts

Communicating in Science

6. Students should be able to conduct research relevant to a scientific issue, evaluate different sources of information including secondary data, understanding that a source may lack detail or show bias
7. Students should be able to organise and communicate their research and investigative findings in a variety of ways fit for purpose and audience, using relevant scientific terminology and representations
8. Students should be able to evaluate media-based arguments concerning science and technology

Science in Society

9. Students should be able to research and present information on the contribution that scientists make to scientific discovery and invention, and its impact on society
10. Students should be able to appreciate the role of science in society; and its personal, social and global importance; and how society influences scientific research

Elements

Elements	Earth and Space	Chemical World	Physical World	Biological World
Building Blocks	1. Students should be able to describe the relationships between various celestial objects including moons, asteroids, comets, planets, stars, solar systems, galaxies and space 2. Students should be able to explore a scientific model to illustrate the origin of the universe 3. Students should be able to interpret data to compare the Earth with other planets and moons in the solar system, with respect to properties including mass, gravity, size, and composition	1. Students should be able to investigate whether mass is unchanged when chemical and physical changes take place 2. Students should be able to develop and use models to describe the atomic nature of matter; demonstrate how they provide a simple way to account for the conservation of mass, changes of state, physical change, chemical change, mixtures, and their separation 3. Students should be able to describe and model the structure of the atom in terms of the nucleus, protons, neutrons and electrons; comparing mass and charge of protons, neutrons and electrons 4. Students should be able to classify substances as elements, compounds, mixtures, metals, non-metals, solids, liquids, gases and solutions	1. Students should be able to select and use appropriate measuring instruments 2. Students should be able to identify and measure/calculate length, mass, time, temperature, area, volume, density, speed, acceleration, force, potential difference, current, resistance, electrical power	1. Students should be able to investigate the structures of animal and plant cells and relate them to their functions 2. Students should be able to describe asexual and sexual reproduction; explore patterns in the inheritance and variation of genetically controlled characteristics 3. Students should be able to outline evolution by natural selection and how it explains the diversity of living things
Systems and Interactions	4. Students should be able to develop and use a model of the Earth-sun-moon system to describe predictable phenomena observable on Earth, including seasons, lunar phases, and eclipses of the sun and moon 5. Students should be able to describe the cycling of matter, including that of carbon and water, associating it with biological and atmospheric phenomena	5. Students should be able to use the Periodic Table to predict the ratio of atoms in compounds of two elements 6. Students should be able to investigate the properties of different materials including solubilities, conductivity, melting points and boiling points 7. Students should be able to investigate the effect of a number of variables on the rate of chemical reactions including the production of common gases and biochemical reactions 8. Students should be able to investigate the reactions between acids and bases; use indicators and pH scale	3. Students should be able to investigate patterns and relationships between physical observables 4. Students should be able to research and discuss a technological application of physics in terms of scientific, societal and environmental impact 5. Students should be able to design and build simple electronic circuits	4. Students should be able to describe the structure, function, and interactions of the organs of the human digestive, circulatory and respiratory systems 5. Students should be able to conduct a habitat study; research and investigate the adaptation, competition and interdependence of organisms within specific habitats and communities 6. Students should be able to evaluate how human health is affected by: inherited factors and environmental factors including nutrition; lifestyle choices; examine the role of micro-organisms in human health
Energy	6. Students should be able to research different energy sources; formulate and communicate an informed view of ways that current and future energy needs on Earth can be met	9. Students should be able to consider chemical reactions in terms of energy, using the terms exothermic, endothermic and activation energy, and use simple energy profile diagrams to illustrate energy changes	6. Students should be able to explain energy conservation and analyse processes in terms of energy changes and dissipation 7. Students should be able to design, build, and test a device that transforms energy from one form to another in order to perform a function; describe the energy changes and ways of improving efficiency	7. Students should be able to describe respiration and photosynthesis as both chemical and biological processes; investigate factors that affect respiration and photosynthesis 8. Students should be able to explain how matter and energy flow through ecosystems
Sustainability	7. Students should be able to illustrate how earth processes and human factors influence the Earth's climate, evaluate effects of climate change and initiatives that attempt to address those effects 8. Students should be able to examine some of the current hazards and benefits of space exploration and discuss the future role and implications of space exploration in society	10. Students should be able to evaluate how humans contribute to sustainability through the extraction, use, disposal, and recycling of materials	8. Students should be able to research and discuss the ethical and sustainability issues that arise from our generation and consumption of electricity	9. Students should be able to explain human sexual reproduction; discuss medical, ethical, and societal issues 10. Students should be able to evaluate how humans can successfully conserve ecological biodiversity and contribute to global food production; appreciate the benefits that people obtain from ecosystems

Appendix E

Survey 1

Considering your experiences to date please rate the statements below against the rating scale in the table.

Each question is optional. Feel free to omit a response to any question; however the researcher would be grateful if all questions are responded to.

No.	**Statement**	**Strongly Disagree**	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**
1	I am sure of myself when I do science					
2	I would consider a career in science					
3	I expect to use science when I get out of school					
4	Knowing science will help me earn a living					
5	I will need science for my future work					
6	I know I can do well in science					
7	*Science will be important to me in my life's work*					
8	*I can handle most subjects well, but I cannot do a good job with science*					
9	*I am sure I could do advance work in science*					
10	*Math has been my worst subject*					
11	*I would consider choosing a career that uses math*					
12	*Math is hard for me*					
13	*I am the type of student to do well in math*					
14	*I can handle most subjects well, but I cannot do a good job with math*					
15	*I am sure I could do advance work in math*					
16	*I can get good grades in math*					
17	*I am good at math*					

This research is being conducted to inform a dissertation that will be submitted to the University of Dublin, in partial fulfilment of the requirements for the degree of Master of Science in Technology & Learning.

Appendix F

Survey 2

Considering your experiences in science to date please rate the statements below against the rating scale in the table.

Each question is optional. Feel free to omit a response to any question; however, the researcher would be grateful if all questions are responded to.

How confident are you to………..

	Statement	**Very Confident**	**Confident**	**Neutral**	**Not very confident**	**Not at all confident**
1	Use technology to work in a team (e.g., shared work spaces, email exchanges, giving and receiving feedback, etc.)?					
2	Use technology to talk with experts or members of communities?					
3	Use technology to keep track of your work on assignments?					
4	Try to solve problems or answer questions that have no single correct solution or answer?					
5	Work in pairs or small groups to complete a task together?					
6	Work with other students to set goals and create a plan for your team?					
7	Create joint products using					

	contributions from each student?					
		Very Confident	**Confident**	**Neutral**	**Not very confident**	**Not at all confident**
8	Present your group work to the class, teacher or others?					
9	Work as a team to use feedback on group tasks?					
10	Give feedback to peers or assess other students' work?					
11	Judge how good and useful online resources are?					
12	Use technology to analyse information (e.g., databases, spreadsheets, graphic programs, etc.)?					
13	Use technology to help to share information (e.g., multi---media presentations using sound or video, presentation software, blogs, podcasts, etc.)?					
14	Compare information from different sources before completing a task or assignment?					
15	Draw your own ideas based on analysis of numbers, facts, or relevant information?					
16	Summarize or create your own					

	interpretation of what you have read or been taught?					
17	Analyse different arguments, perspectives or solutions to a problem?					
		Very Confident	**Confident**	**Neutral**	**Not very confident**	**Not at all confident**
18	Use evidence to develop arguments?					
19	Structure data for use in written products or oral presentations (e.g., creating charts, tables or graphs?					
20	Communicate your ideas using media other than a written paper (e.g., posters, video, blogs, etc.)					
21	Prepare and deliver an oral presentation to the teacher or others?					
22	Answer questions in front of an audience?					
23	Decide how you will present your work?					
24	Use idea creation techniques such as brainstorming?					
25	Generate your own ideas about how to solve a problem or answer a question?					
26	Test out different ideas and work to improve them?					
27	Invent a solution to difficult problems?					

28	Create something new that can help you express your ideas?					
29	Take the lead when faced with a difficult problem or question?					
30	Choose your own topics of learning or questions?					
31	Plan the steps you will take to accomplish a difficult task?					
32	Choose for yourself what to study or what to use to help you study?					
33	Track your own progress and change things if you are not working the way that you should be to complete a task?					
34	Assess the quality of your work before it is completed?					
35	Use peer, teacher or expert feedback to change your work?					
36	Use technology or the Internet to help you learn things for yourself (e.g tutorials, self--- instructional websites, etc.)?					
37	Select the right technology tools or resources for completing a task?					

This research is being conducted to inform a dissertation that will be submitted to the University of Dublin, in partial fulfilment of the requirements for the degree of Master of Science in Technology & Learning.

Appendix G

Ethics Approval

An investigation into the use of the Bridge21 model to deliver the new Junior Cycle Science specification.

Status | View | Assign Supervisor

Current Status	Submission date	Last Status Update	Academic Supervisor / Lead Researcher	Application Number
Approved	Wednesday, November 2, 2016 - 15:26	Tuesday, February 7, 2017 - 10:05	dtangney	20161102

No workflow transitions are possible at this time.

Status:
Approved

Timeline of state changes for this application

Appendix H

Question	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1	0	3	4	10	2
	0	1	2	12	4
2	5	6	5	2	1
	3	5	6	3	2
3	1	7	8	1	2
	1	5	3	9	1
4	1	1	11	5	1
	1	3	11	3	1
5	1	2	12	3	1
	1	2	11	4	1
6	0	2	5	10	2
	0	0	3	12	4
7	2	7	8	0	2
	1	5	8	2	3
8	2	8	3	6	0
	4	9	2	4	0
9	1	3	5	9	1
	0	1	5	10	3
10	3	4	2	3	7
	5	4	1	3	6
11	5	7	2	4	1
	2	5	1	7	4
12	2	4	2	5	6
	1	4	1	7	6
13	2	8	5	1	3
	0	5	5	5	4
14	1	6	6	4	2
	1	8	7	2	1
15	3	6	5	4	1
	2	3	5	6	3
16	1	5	7	5	1
	1	3	6	6	3
17	3	4	7	3	2
	2	3	6	5	3

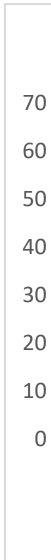
Statement	Very Confident	Confident	Neutral
1	3	4	3
	4	5	5
2	2	5	2
	4	7	1
3	3	6	2
	4	6	5
4	2	3	4
	3	4	6
5	5	4	3
	7	5	4
6	4	5	4
	5	7	6
7	3	6	3
	5	7	5
8	4	5	2
	6	6	5
9	3	7	4
	5	9	3
10	5	3	3
	5	5	5
11	2	6	2
	5	7	3
12	3	5	4
	5	8	4
13	1	5	3
	3	8	4
14	2	1	3
	4	4	5
15	3	2	4
	5	5	6
16	2	3	5
	4	6	3
17	1	3	4
	3	6	5
18	2	2	5
	4	4	6
19	3	5	3
	5	7	4
20	4	5	1
	5	7	5
21	2	2	2
	4	5	5
22	2	3	3
	3	5	5
23	4	5	4
	6	5	5
24	4	5	2
	5	7	4
25	4	8	1

	6	7	5
26	3	6	3
	5	6	6
27	3	4	2
	5	6	4
28	5	4	2
	5	7	4
29	3	5	2
	5	7	3
30	1	2	3
	3	4	7
31	3	4	4
	5	5	6
32	3	6	5
	5	8	4
33	4	4	4
	5	7	4
34	2	3	5
	4	4	7
35	4	5	3
	5	6	3
36	3	4	1
	4	7	3
37	4	5	2
	6	6	0

Not Very Confident	Not at all Confident
6	3
4	1
7	3
5	2
6	2
4	0
7	3
4	2
5	2
2	1
4	2
1	0
5	2
2	0
5	3
1	1
3	2
1	1
4	4
2	2
5	4
2	2
5	2
2	0
7	3
3	1
8	5
4	2
6	4
2	1
7	2
5	1
6	5
3	2
5	5
2	3
5	3
2	1
5	4
1	1
6	7
2	3
8	3
5	1
5	1
3	0
5	3
2	1
4	2

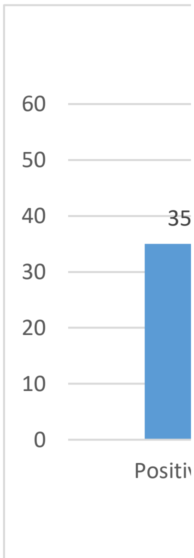
1	0
4	3
1	1
7	3
3	1
5	3
2	1
5	4
2	2
9	4
4	1
5	3
2	1
4	1
2	0
3	4
1	2
5	4
2	2
4	3
3	2
7	4
4	1
5	3
5	2

CT		Very Confi	Confident	Neutral	Not very cc	Not at all confident
Pre	4	2	3	4	7	3
Post		3	4	6	4	2
	14	2	1	3	8	5
		4	4	5	4	2
	15	3	2	4	6	4
		5	5	6	2	1
	16	2	3	5	7	2
		4	6	3	5	1
	17	1	3	4	6	5
		3	6	5	3	2
	18	2	2	5	5	5
		4	4	6	2	3
		12	14	25	38	24
		23	29	31	20	11



	Positive res	Neutral res	Negative responses
Pre-survey	26	25	62
Post-survey	52	31	31

Communic	19	3	5	3	5	3
		5	7	4	2	1
	20	4	5	1	5	4
		5	7	5	1	1
	21	2	2	2	6	7
		4	5	5	2	3
	22	2	3	3	8	3
		3	5	5	5	1
	23	4	5	4	5	1
		6	5	5	3	0

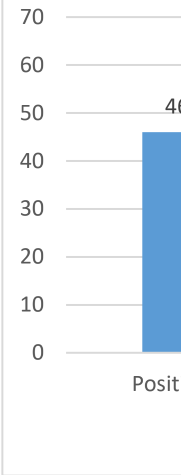


	Positive res	Neutral res	Negative responses
Pre-survey	35	13	47
Post-survey	52	24	19

Creativity and innovation

24	4	5	2	5	3

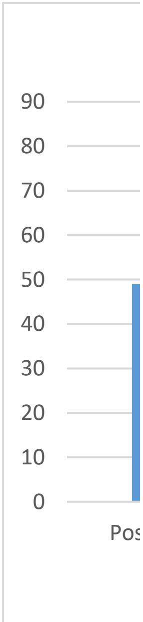
	5	7	4	2	1
25	4	8	1	4	2
	6	7	5	1	0
26	3	6	3	4	3
	5	6	6	1	1
27	3	4	2	7	3
	5	6	4	3	1
28	5	4	2	5	3
	5	7	4	2	1



	Positive res	Neutral res	Negative responses
Pre-survey	46	10	49
Post-survey	59	23	13

Self-direction

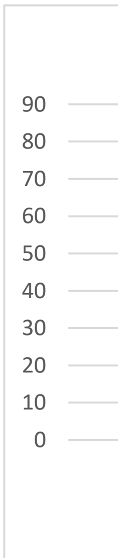
29	3	5	2	5	4
	5	7	3	2	2
30	1	2	3	9	4
	3	4	7	4	1
31	3	4	4	5	3
	5	5	6	2	1
32	3	6	5	4	1
	5	8	4	2	0
33	4	4	4	3	4
	5	7	4	1	2
34	2	3	5	5	4
	4	4	7	2	2
35	4	5	3	4	3
	5	6	3	3	2



	Positive res	Neutral responses
Pre-survey	49	26
Post-survey	83	34

Collaboration Skills

5	5	4	3	5	2	7
	7	5	4	2	1	3
6	4	5	4	4	2	6
	5	7	6	1	0	1
7	3	6	3	5	2	7
	5	7	5	2	0	2
8	4	5	2	5	3	8
	6	6	5	1	1	2
9	3	7	4	3	2	5
	5	9	3	1	1	2
10	5	3	3	4	4	8
	5	5	5	2	2	4

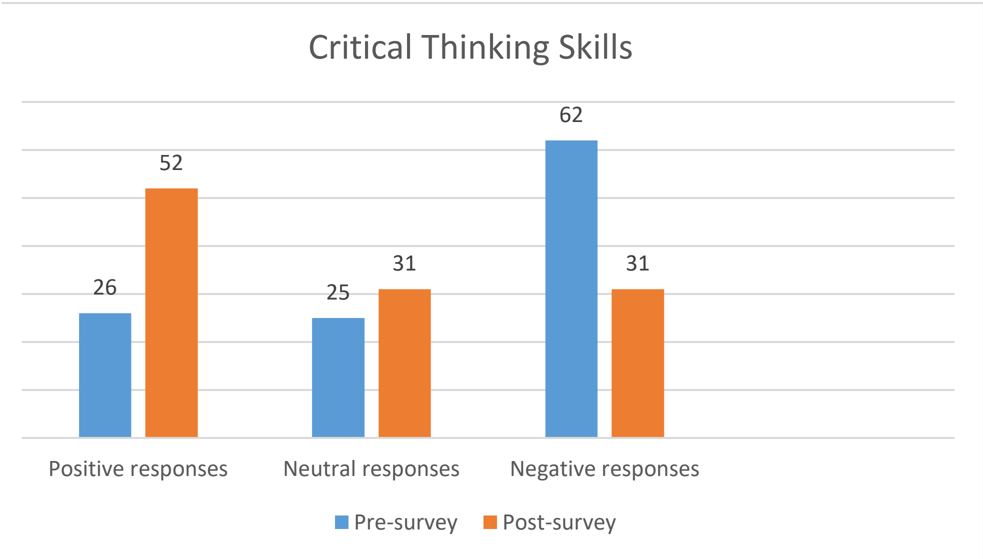


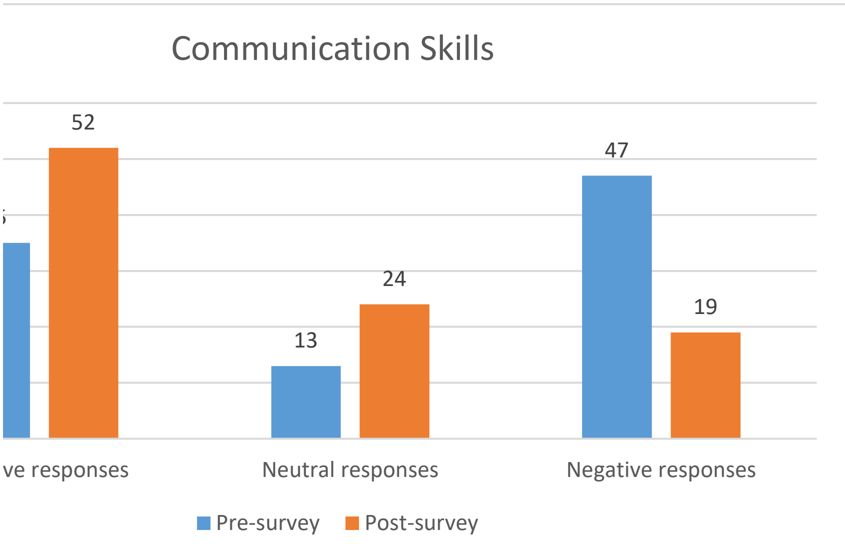
	Positive res	Neutral responses
Pre-survey	54	19

Post-surve|	82	28

USING TECI	11	2	6	2	5	4	9
		5	7	3	2	2	4
	12	3	5	4	5	2	7
		5	8	4	2	0	2
	13	1	5	3	7	3	10
		3	8	4	3	1	4
	1	3	4	3	6	3	9
		4	5	5	4	1	5
	2	2	5	2	7	3	10
		4	7	1	5	2	7
	3	3	6	2	6	2	8
		4	6	5	4	0	4
	36	3	4	1	7	4	11
		4	7	3	4	1	5
	37	4	5	2	5	3	8
		6	6	0	5	2	7

Using Tech	Positive re:	Neutral res	Collaborat	Positive re:	Neutral responses		Negative re
Pre-survey	51	19	Pre-survey	54	19		41
Post-surve|	89	26	Post-surve|	82	28		14


Critical Thinking Skills
62
52
26
25
31
31
Positive responses
Neutral responses
Negative responses
Pre-survey
Post-survey


Communication Skills
52
47
24
13
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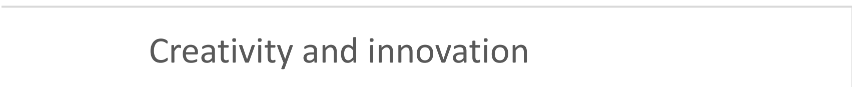
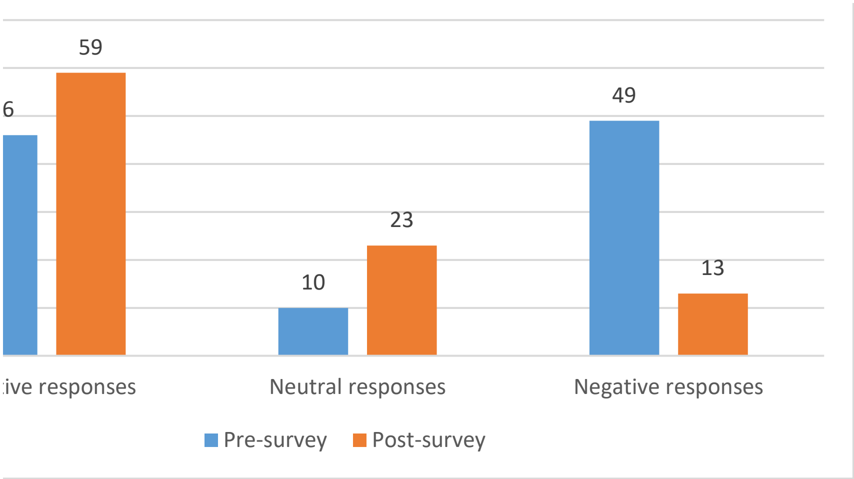
ve responses
Neutral responses
Negative responses
Pre-survey
Post-survey


Creativity and innovation


6
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ive responses
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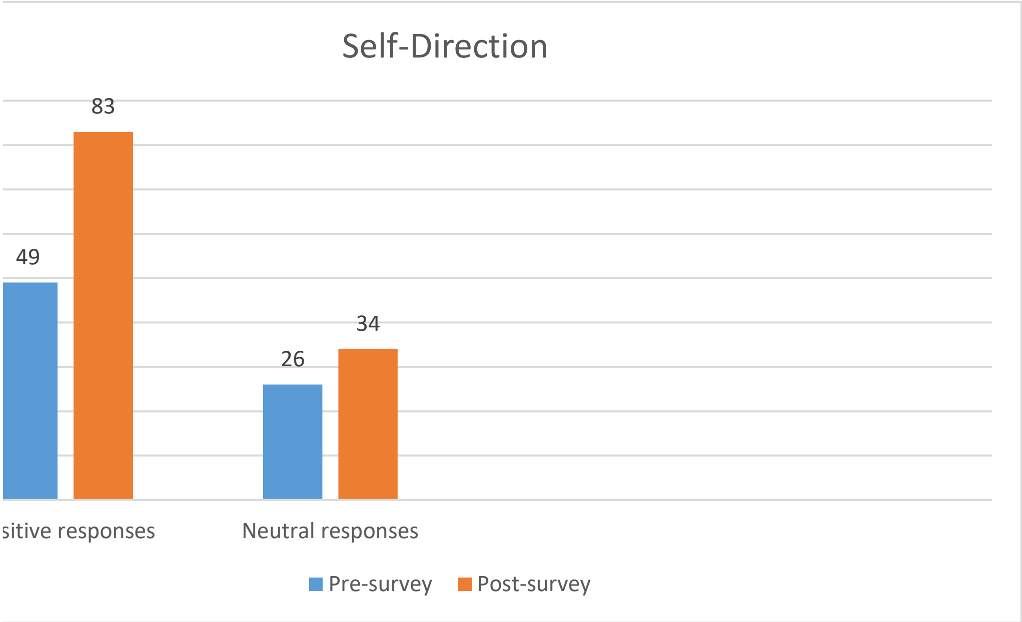
Negative responses
Pre-survey
Post-survey


Self-Direction
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49
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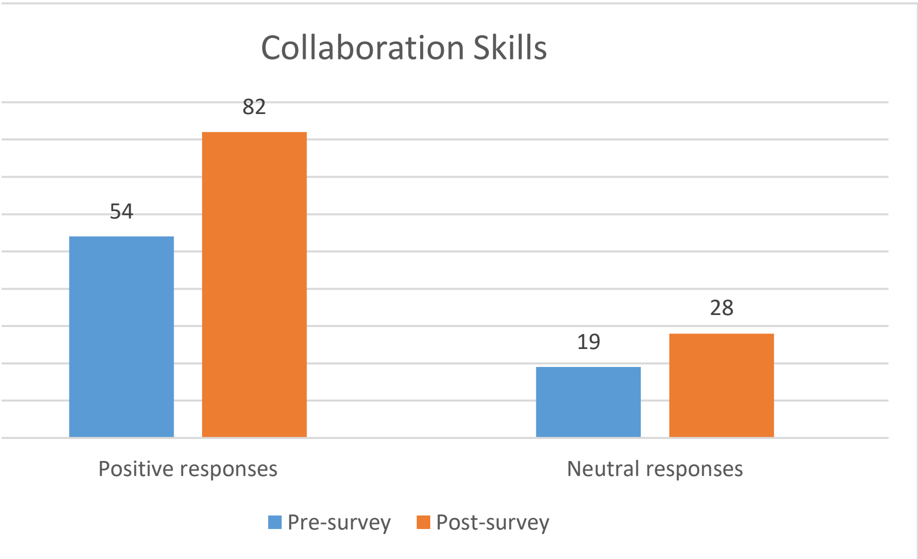
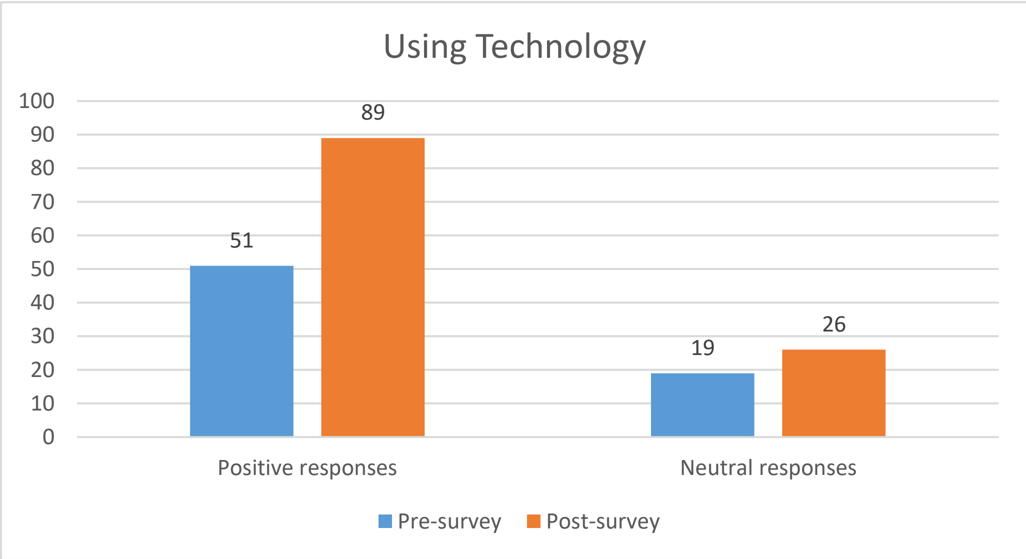
34
sitive responses
Neutral responses
Pre-survey
Post-survey


Collaboration Skills
82
54
19
28
Positive responses
Neutral responses
Pre-survey
Post-survey



Using Technology
100
90
80
70
60
50
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30
20
10
0
89
51
19
26
Positive responses
Neutral responses
Pre-survey
Post-survey

:sponses

Appendix I

Transcript

Focus group interview

Five students

30 minutes

Researcher: Did you enjoy the science workshops you took part in over the last number of weeks?

Student one: Yeah,

All: Nod in agreement

Researcher: What did you enjoy about them?

Student two: Working in groups, it was fun

All: Yeah, nod in agreement

Student two: It's better working in groups because you can help each other figure things out

Student four: Yeah it's good working in groups because, like, it's not just your knowledge it's other peoples as well and that makes it easier

All: nod, yeah

Student three: I liked using computers and our phones and going out of the classroom

Student four: I liked the freedom, doing what you wanted

Researcher: What do you mean by freedom?

Student four: You had to think for yourself, decide what to do next

Researcher: Can you explain that a bit more for me?

Student four: You usually explain things to us and in those classes we had to do it for ourselves

All: Yeah, nod in agreement,

Student two: I didn't like getting up and presenting stuff

Student one: I didn't like that either

Researcher: You didn't like presenting to the class, why not?

Student one: just didn't

Student two: standing up in front of the whole class is hard

Student four: I didn't mind coz that's in everything, when you get older and have a job like, you'll need to get good at it [presenting] for when your older, especially if you want a job that pays lots of money

Student three: I didn't mind because like [student four] says if you want to go far your gonna have to pitch your ideas to people, so like you have to get use to talking in front of people

Research: So you think that it is a useful skill to have?

Student four: Yeah, exactly

All: yeah nodding

Student two: but I still didn't like it though

All: laugh

Researcher: what do you think about presentations [student five]?

Student five: they're grand, it's hard, but I suppose you'll have to do it when your older so you need the practice. I liked watching everyone else present, it got a bit easier the last time because you were use to it.

Researcher: Was there anything positive about presenting to the groups, did it help with your learning or understanding of the topic?

Student one: Well it's better than just sitting in a classroom taking down notes and I guess you did learn stuff from other peoples presentations

All: nod in agreement

Student four: You could get ideas for the next time you are going to present from watching other people, like its helps your presentation skills because other people might put in things you didn't put or put things in a different way and you might remember that you didn't do that and stuff and you will the next time

Student three: it was good to see what other people talked about compared to you, like some people saw things differently to the way you did and you learned things from watching other peoples presentations

All: yeah

Researcher: Was there many differences between how we study science during class time and the workshops we did after school?

Student two: Yeah working in groups and leaving the lab

Researcher: ok, but do you not work in groups when you are doing experiments in science class?

Student two: yeah but this was different, in experiments you tell us what to do but we had to direct this ourselves in the those lessons even when we weren't doing experiments

Student four: you learn more when you're thinking for yourself and its more interesting figuring it out with your friends or for yourself instead of being told the next step you can decide with the group what you're going to try next, it's more exciting that way

Student one: it's more fun doing it that way as well and it stays in your head better

Student two: also like when you work in groups you get a second opinion and I liked that

Student five: lets say if you had an idea in your head on a way to solve the problem sort of and you were on your own you wouldn't be that confident but if three other people agree with you then you are more confident to keep trying to work it out that way and you'll keep trying together

Researcher: very good, you said you liked leaving the lab can you tell me more about what you mean when you say that?

Student two: I liked when we were in the computer room or outside

Researcher: why?

Student two: because probably because we were using the computers or our phones

Student four: yeah I liked that too why can't we use our phones in class?

Research: I guess because of the school rules and people might use them for things your not supposed to.

Student four: that's stupid it would be so much if we could use our phones in class because then we could do more of those things and it would be more fun and interesting

Researcher: when you say more of those things what do you mean?

Student four: like researching for yourself or the atom thing

Researcher: the simulator?

Student four: yeah, I liked it when we used the simulator,

Researcher: Why?

Student four: it was fun using the computer it was easier to picture it then because the computer gave a picture of like an atom, you can't picture it when you learning from the book as easy

Student five: I think it's because it moves on the computer and you can change things on the computer whereas you can't in the book and it's boring to draw it out, it's more fun on the computer and you don't need to draw it out

Student one: I think you remember it better because you remember the time you had fun and then you remember what you were learning

Student four: If it's boring when you're learning it you won't remember it but if it's fun you will

Student one: also like if you go wrong you know straight away and you can learn from the mistake and fix it straight away and like your friends can help you fix it together because they might know where you made the mistake

Student two: I really liked when we went outside

Researcher: oh yeah, why?

Student two: because like we could go off with our group and try and solve things ourselves and it was like we were like real science people

Student four: oh yeah that was good

Student five: that's another thing I liked, the stuff we were doing wasn't like a yes or no or right and wrong they were more like a puzzle and you had to work together to solve it I really liked that you know the answer wasn't just in the book

All: nod in agreement

Student four: the problems were hard but they made you think more for yourself and you learned more I think

All: yeah

Researcher: Do you think you would like to work in science after you leave school?

Student four: I already know I am going to work in science

Researcher: oh yeah, what area of science are you going to work in?

Student four: not sure but I am going to work in science

Researcher: Why?

Student four: because I like science and you can make lots of money in science

Researcher: Very good, what about everyone else

Students: inaudible

Researcher: None of you would be interested in a career in science just [student four], why not?

Student two: it's not interesting

Student three: I'm just not passionate about it, I want to be an actor

Student four: Yeah but, if you want to make money something like science is was you need

Student one: I just don't think it's of any use to me, like I don't know what working in science means, what would you work at? What job would you have?

All: yeah?

Student four: a doctor!

Student five: It's not useful in my day to day life, I don't ever really use anything we learn and you have to be really smart to make to big discovery

Researcher: How many of you would take a science subject for your leaving cert?

All: [put hands up]

Researcher: Why would you study a science subject for the leaving certificate if you are not planning on using it after school?

All: [blank faces]

Student one: because it's good to have a science subject

Researcher: that's true

Bell rings

Researcher: ok that is the bell you better go to class, thank you for participating in the interview.

[Recorder off]

Appendix J

INDIVIDUAL REFLECTION SHEET

TWO THINGS I DID WELL THIS TIME:

1

2

One THING I WOULD LIKE TO IMPROVE ON NEXT TIME:

1.

Appendix K

BUILD AN ATOM

PART I: ATOM SCREEN

Build an Atom simulation (http://phet.colorado.edu/en/simulation/build-an-atom)

1. Explore the ***Build an Atom*** simulation with your group. As you explore, talk about what you find.

2.
   a) List two things your group observed in the simulation.

   b) What particle(s) are found in the center of the atom?

3. Play until you discover which **particle(s)** determine(s) the name of the **element** you build. What did you discover?

4. What is the **name** of the following atoms?
   a) An atom with 3 protons and 4 neutrons: ___________
   b) An atom with 2 protons and 4 neutrons: ___________
   c) An atom with 4 protons and 4 neutrons: ___________

5. Play with the simulation to discover which particles affect the **charge** of an atom or ion.
   a) Fill in the blanks below to show your results:

      Neutral atoms have __the same number of__ protons and electrons.

      Positive ions have ______________________ protons than electrons.

      Negative ions have ______________________ protons than electrons.

   b) Develop a relationship (in the form of a single sentence or equation) that can predict the charge based on the number and types of particle.

6. Play with the simulation to discover what affects the **mass** number of your atom or ion.

   a) What is a rule for determining the mass number of an atom or ion?

7. Practice applying your understanding by playing 1st and 2nd levels on the game screen.

PART II: SYMBOL SCREEN

8. Using the *Symbol* readout box, figure out **which particles** affect each component of the atomic symbol.
   a) In the atomic symbol below, label each letter (*a*, *b*, *c*, and *d*) with:
      - the **particle(s)** used to determine the letter, and
      - **how** the value of each letter is determined.

$$ {}^{d}_{c}a^{b} $$

9. Create a definition (using a complete sentence) for each of these items based on your labels from the atomic symbol above.

   a) Element Symbol

   b) Charge

   c) Atomic Number

   d) Mass Number

10. Practice applying your understanding by playing the 3rd and 4th game levels. Play until you can get all the questions correct on the 4th level.

11. In addition to atomic symbol, we can represent atoms by name and mass number.
    a) Complete the table below:

Symbol	Name
${}^{12}_{6}C^{+1}$	Carbon-12
${}^{18}_{9}F$	
${}^{11}_{5}B$	

   b) Each representation (Symbol and Name) in the table above provides information about the atom. Describe the similarities and differences between the *Symbol* and *Name* representations.

PART III: ISOTOPES

12. Play with the simulation to determine:
    a) Which particles affect the stability of the atom? ___________________
    b) Which particles do not affect the stability of the atom? _____________

13. What are the names of the stable forms of oxygen?
    a) Oxygen-16
    b) Oxygen-___
    c) Oxygen-___
    d) List all of the things that are the same about these atoms (ignore the electrons).

    e) List all of the things that are different about these atoms (ignore the electrons).

14. The atoms in the previous question are **isotopes** of each other. Based on this information, list the requirements for two atoms to be isotopes of each other.

15. Test your understanding of isotopes by examining the relationships between the pairs of atoms listed below:

Atom 1	Atom 2	Relationship between atom 1 and atom 2
$^{12}_{6}C$	$^{13}_{6}C$	☐ Isotopes ☐ Same Atom, Not Isotopes of Each Other ☐ Different Element
Carbon-12	$^{12}_{6}C$	☐ Isotopes ☐ Same Atom, Not Isotopes of Each Other ☐ Different Element
Argon-40	Argon-41	☐ Isotopes ☐ Same Atom, Not Isotopes of Each Other ☐ Different Element
$^{11}_{5}B$	Boron-10	☐ Isotopes ☐ Same Atom, Not Isotopes of Each Other ☐ Different Element
An atom with 13 protons and 13 neutrons	An atom with 14 protons and 13 neutrons	☐ Isotopes ☐ Same Atom, Not Isotopes of Each Other ☐ Different Element

EXERCISES

16. The periodic table has a great deal of information about every atom. Using your periodic table, answer the following questions:

    a) What is the atomic number of chlorine (Cl)? ____

    b) What is the atomic number of tungsten (W)? ____

    c) How many protons are there in any Cl atom?____

    d) How many protons are there in any Te atom? ____

    e) Can you tell from the periodic table exactly how many neutrons are in an atom?

17. Complete the following table:

Name	Symbol	Atomic number	Mass Number	Number of neutrons	Number of Electrons	Charge
hydrogen-2	^{2}H	1	2	1	1	0
	^{3}H					
sodium-22	$^{22}Na^{+}$				10	
		12	24		12	
		12	25		13	
	$^{46}Ti^{-2}$					
	^{107}Ag					
	$^{19}F^{-1}$					
carbon-12					6	
carbon-13					6	
carbon-14					6	
carbon-12					7	
carbon-12					5	
	^{4}He					
		8		8	10	
argon-40		18			18	
	^{70}Ga					
	$^{70}Ga^{+3}$					
		4	9		2	
		7		8	8	

18. To test your knowledge of isotopes, draw arrows between all pairs of atoms in the table above that are isotopes of each other.

Appendix L

Appendix L

Interview Protocol

1. **Did you enjoy the science workshops you took part in over the last number of weeks?**
2. **What did you enjoy about them?**
3. **Was there many differences between how we study science during class time and the workshops we did after school?**
4. **What was your favourite lesson we did and why?**
5. **Do you like studying Science in school?**
6. **What do you like/not like about studying Science?**
7. **Do you think you would like to work in science after you leave school?**
8. **How many of you would take a science subject for your leaving cert?**