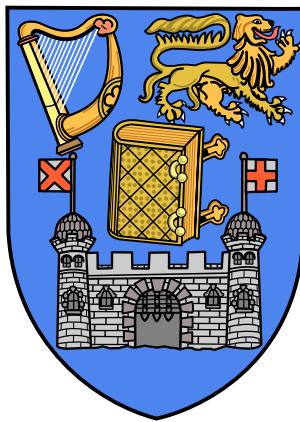


Evaluation of STEM@University Experiences for Transition Year Students

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A Thesis submitted for a Research Masters degree

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2022

Declaration

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Abstract

This master's monograph and research present a study on the influence of STEM@University (a non-formal, university-school intervention) on a Transition Year student's STEM identity, through the measurement of STEM capital, self-efficacy, and autonomy. This 6-week long learning intervention sought to provide a learning opportunity that would enhance the student's STEM identity and university readiness, at this transitional time in their formal education. Given the COVID-19 restrictions, the experience was entirely delivered remotely via Microsoft Teams. The learning experience was a blend of synchronous and asynchronous sessions, and it provided opportunities to enhance self-efficacy and learner autonomy.

An assessment of the student's experience was conducted using three instruments, the Index of Science Capital, Sources of Science Self-Efficacy and Academic Self-Regulation Questionnaire, a review of student artefacts including their reflections, a pre- and post-experience survey and a post-experience focus group. The data collected provided quantitative and qualitative insight into the experiences of 12 individual students.

Upon analysis of the data collected from the students' STEM capital, sources of science self-efficacy and Relative Autonomy Index (RAI), no statistically significant change occurred in these students during their time at STEM@University. These quantitative results are contrasting with the qualitative data that was collected in a focus group format that indicated that the students' felt they had become more autonomous learners, more aware of STEM careers and areas of study and that participating in the STEM@University made STEM a less intimidating environment for them.

This study finds that of the 12 students, 6 had an overall positive shift in their STEM identity, while 4 saw a negative shift. This research concludes that while a portion of students indicated that STEM@University did achieve its desired goals, these students may already be comfortable with working autonomously, and the programme suited their learning preferences. In future iterations of student evaluation, these selected instruments may be too blunt to accurately assess the desired students' outcomes, however securing a larger sample size will be essential to accurately evaluate their effectiveness and the STEM@University experience for Transition Year students.

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Abbreviations

DES	Department of Education and Skills
MOOC	Massive Open Online Courses
NCCA	National Council for Curriculum and Assessment
OECD	The Organization for Economic Co-operation and Development
PISA	Programme For International Student Assessment
RAI	Relative Autonomy Index
SDT	Self-Determination Theory
SRL	Self-Regulated Learning
SRQ-A	Self-Regulated Questionnaire – Academic
STEM	Science, Technology, Engineering and Mathematics
TIMMS	Trends in International Mathematics and Science Study
TWC	Trinity Walton Club
TY	Transition Year

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1 Introduction

1.1 Thesis Outline

This thesis contains 5 chapters.

Chapter 1 of this thesis aims to contextualise this experience within the broader STEM landscape. It will examine STEM education as it pertains to this programme. Formal, non-formal and informal learning will be discussed, as this course is built to lie in a space between formal education and a STEM club. Transition Year in Ireland and Trinity Walton Club are introduced and outlined, giving the background for STEM@University.

In Chapter 2, the theoretical basis is detailed as I then move to discuss the learning behind STEM capital, self-efficacy, and autonomy. At times these are meshed, e.g., in Section 2.1, given the role that identity and capital play in subject choice. Within this section, the different instruments, and methods available for measuring student STEM Capital, self-efficacy and autonomy are introduced.

Chapter 3 discusses the methodology of this study. The research questions are stated as well as the methods in which this study will attempt to answer them. Reasoning is given for instrument selection during this study.

Chapter 4 describes STEM@University, and it is placed in situ alongside what theoretically is desirable from a literature perspective.

In Chapter 5, the results from the quantitative instruments and the qualitative focus group are presented.

Finally, conclusions are discussed in Chapter 5 and the implications of this study for research and practice are presented.

1.2 Background of the Study

In this section I will provide an overview of the relevant background information that was essential to this research study. It aims to provide essential contextual information on STEM education, a comparison of educational environments, an overview of Trinity Walton Club, a review of Transition Year in Ireland and related opportunities for

students, to give the reader a portrayal of the context in which this study was completed.

1.2.1 STEM Education

To evaluate STEM, it's important to look at some of the differing perspectives on what STEM is. This section will look at STEM from a global perspective and show what the Irish Department of Education and Skills mean when they use the acronym, and this importance that is placed on it within Government policy.

While STEM is an acronym for Science, Technology, Engineering and Mathematics, there is no agreed consensus on what STEM education is (McLoughlin et al., 2020).

“Definitions of STEM range from simple referencing of the four STEM disciplines; educational approaches at the intersections of any number of the four disciplines; to referencing all four STEM disciplines in an integrated manner.”
(McLoughlin et al., 2020).

A recent literature review of 53 relevant STEM education publications examined existing STEM frameworks and identified 7 core characteristics of STEM education (McLoughlin et al., 2020). Each of the reviewed core frameworks contained some or all the following characteristics:

- Core STEM Competences
- Problem Solving Design and Approaches
- Disciplinary and Interdisciplinary Knowledge
- Engineering Design and Practices
- Appropriate Use and Application of Technology
- Real World Contexts
- Appropriate Pedagogical Practices

Within Ireland, the Department of Education skills state that *“STEM education is multi-faceted and goes well beyond the main disciplines that constitute the acronym STEM.”* (Department of Education and Skills, 2017). The Department of Education and Skills (2017) highlight that STEM education doesn't require just the teaching of standalone subjects, but instead needs a cross-disciplinary approach. In STEM education students

use their creativity, knowledge, and skills within and across disciplines and in real life situations. It builds on existing content knowledge and understanding built in those in those standalone subjects.

In Ireland, the Department of Education and Skills has stated a vision to become internationally recognized for providing STEM education that *“nurtures curiosity, inquiry, problem-solving, creativity, ethical behaviour, confidence, and persistence, along with the excitement of collaborative innovation”* (Department of Education and Skills, 2017). The STEM Education Policy Statement 2017-2026 sets out a clear vision to shape the direction of STEM education in Ireland.

“ In line with our ambition to have the best education and training service in Europe by 2026, Ireland will be internationally recognised as providing the highest quality STEM education experience for learners that nurtures curiosity, inquiry, problem-solving, creativity, ethical behaviour, confidence, and persistence, along with the excitement of collaborative innovation” (Department of Education and Skills, Ireland: STEM Education Policy Statement 2017-2026, p. 12)

One indicator of success of this policy is to achieve a 20% increase in students studying Leaving Certificate physics, chemistry, engineering and technology from 2016 to 2026. Since 2016, there has been a slight decrease in students studying engineering, slight increases in students studying physics and chemistry and an increase of 32% of students studying technology (Department of Education and Skills, 2017). A reason for this policy is that it is stated that there is expected to be a shortfall in STEM workers. Demand is for these workers is set to grow between 2015 and 2025, while it is acknowledged that many Irish learners do not have the specific skills to meet this demand (Department of Education and Skills, Ireland: STEM Education Policy Statement 2017-2026, p. 10).

The STEM Education policy has a core objective that learners of all backgrounds, genders, and ability can be active participants in STEM (Department of Education and Skills, 2017). It is aimed to increase the numbers of female students studying Junior Cycle wood technology, technical graphics, metalwork, technology and science by 40%

from 2016 (Department of Education and Skills, 2020). In the years from 2016 – 2019, there has been increases in the numbers of females studying wood technology by 30%, technical graphics by 46%, metalwork by 25%, technology by 41% and science by 7%.

1.2.1.1 How STEM Education in Ireland compares internationally

The OECD Programme for International Student Assessment (PISA) measures “a 15-year-olds’ ability to use their reading, mathematics and science knowledge and skills to meet real-life challenges” and is widely used to compare the education systems of OECD countries. (OECD, 2021). In the 2018 PISA exam for scientific literacy, Ireland’s students performed significantly above the OECD average of 489 scoring 496 points. Ireland’s score was ranked 17th out of the 37 OECD countries and 22nd out of all 78 countries participating in PISA (McKeown et al., 2019). There is no significant difference between the performance of males and females in scientific literacy as assessed by PISA (McKeown et al., 2019; OECD, 2019b).

In the 2018 PISA exam for mathematics. Ireland’s students performed significantly above the OECD average of 489, scoring 499.6 points. Ireland’s score was ranked 16th out of the 37 OECD countries and 21nd out of all 78 countries participating in PISA (McKeown et al., 2019). There is no significant difference between the performance of males and females in scientific literacy as assessed by PISA (McKeown et al., 2019; OECD, 2019b).

TIMSS is an international assessment that aims to monitor trends in student achievement in mathematics, science, and reading (TIMSS & PIRLS International Study Center, 2021). In the most recent TIMSS data (2019) Ireland has scored a mean score of 524 in mathematics and 523 in science for second year students, both which are significantly above the mean score of 500. Ireland is ranked 10th out of 39 participating countries in Mathematics and 10th out of 39 participating countries in science. Ireland has increased both its scores in mathematics from 519 in 1995 to 524 and science from 518 in 1995 to 523. (Mullis et al., 2020)

1.2.2 Formal, Non-Formal and Informal Education

Within education three forms of learning, formal; non-formal; and informal are identified. A review of the multiple definitions of each was conducted (Roche et al., 2019) of these three forms of education.

It has been said by Werquin (2007) that these definitions are not strict, but lie on a spectrum with one definition blending to the next. Moreover, all three forms of learning are recognised by the OECD as being invaluable to progress. They say that their 2030 Learning Framework

“...acknowledges the importance of formal, non-formal and informal learning alongside education that is bounded by formal curricula and instructional strategies” (OECD, 2019).

The role of higher education and out of school settings within the student’s STEM educational experience has also been acknowledged at national level by the DES (Department of Education and Skills, Ireland: STEM Education Policy Statement 2017-2026, p. 8).

Formal education is considered as education that takes place in a structured manner within the confines of an educational institution. This type of education is recognized by formal qualifications and awards. It contains learning objectives is intentional from the learner’s point of view and broadly didactic (Roche et al., 2019)).

Non-formal education relates to any organized and sustained educational activity that does not correspond exactly to the definition of formal education. As a result, this form of education can take place both inside and outside formal education institutions (NCEVER, 2021). It has specific learning objectives, is intentional and broadly dialogic or didactic. It could lead to a qualification. (Roche et al., 2019). Science centres, museums, programs run by educational institutions and youth organisations such as scouts have been described as places where non-formal education can take place (Eshach, 2007; Filippopoliti & Koliopoulos, 2014; Hill, 2001). It is also said that institutions or initiatives that aim to fulfil the role of *“life-long learning”* fall under the remit of Non-Formal Education (Hoppers & Institut international de planification de l’éducation, 2006).

Informal education is mainly unstructured and often accidental learning experiences. Is it said to happen within day-to-day activities. It does not have learning objectives, may or may not be intentional and is autonomous. It does not lead to a qualification (Roche et al., 2019).

Eshach (2007) has described how non formal education in the form of science field trips can be effective in stimulating the affective domain within students, an area that can be neglected by formal education. The benefits of informal education on the learner have been documented (Denson et al., 2015; Moote et al., 2019) and its importance to society has been noted by the OECD (Werquin & OECD, 2009).

Within the Irish education environment there are many different STEM organisations and competitions that sit alongside the formal education space that would be best classified as informal but enabled and facilitated by the work of teachers in the formal education sector. Examples of such organisations would be competitions in the mode of a traditional “Science Fair”, e.g. BT Young Scientist and SciFest, and more specific competitions like The Big Idea, CANSAT and F1 in Schools.

1.2.3 Trinity Walton Club

Trinity Walton Club (TWC) is a non-formal STEM learning environment for children between the ages of 13-18 located in Trinity College Dublin Ireland. It is a 4-year programme for learners that takes place alongside the school year on Saturdays in the School of Physics, Trinity College Dublin. This programme runs outside of the formal education system, and provides an extra-curricular development experience for STEM engaged youth, during this highly formative stage in their lives. While in the club, learners (called Alphas- after the Helium particle which was critical to Ernest Walton’s Nobel Prize winning experiment) take part in 3 streams based on physics, maths and technology and engineering.

The club is named after Ernest Walton, Ireland’s only Nobel Prize winning physicist, who won for the prize along with his colleague John Cockcroft for the first artificial splitting of the atom. He spent his undergraduate studies and majority his time as a Professor in Trinity College Dublin. Despite being one of the people at the forefront of nuclear physics, his work benefited from the collaboration of his colleagues Cockcroft and

Rutherford, and it is in this spirit that work in this STEM club is undertaken (Roche et al., 2016).

The club was founded in 2014 and at the time of writing has had over 3200 educational interactions through the Club and Camp programmes. TWC strives for a gender balance across the student and educator cohorts. The average gender breakdown across all its programmes is 47% female. TWC's learning framework is inspired and aligned by the OECD 2030 Learning Compass (OECD, 2019a))

"The OECD Learning Compass 2030 sets out a "learning framework", not an "assessment framework". The framework offers a broad vision of the types of competencies students need to thrive in 2030, as opposed to what kind of competencies should be measured or can be measured." (OECD, 2019)

TWC 's programme seeks to build each individual learner's STEM capital (a concept which I will examine in greater detail in this research) by delivering a non-formal, highly social, student-centred, and collaborative teaching and learning experience. The club programme can continue for students for up to 4 years and runs on Saturdays alongside the academic year (Sept-June). TWC's timetabling is cognisant of the demands on exam students and finishes early in the year for students who are sitting the Junior Cycle examinations and could possibly be sitting the Leaving Certificate.

The core competencies the teaching and learnings seeks to develop are:

- Collaboration
- Critical Thinking
- Creative Problem Solving
- Communication
- Research
- Autonomy
- Curiosity
- Leadership in Society

1.2.3.1 *Where does Trinity Walton Club lie?*

TWC lies within the non-formal part of the education landscape, leveraging aspects of both formal and informal learning. For example, learning at the club is structured with specific learning outcomes organised into specific desired knowledge, skills and attributes, however attendance is not mandatory and there are no exams. While it is endorsed by Trinity College Dublin, it does not lead to any specific qualification or recognition being awarded to learners of the club. Throughout their journey learners engage in sessions, workshops and project blocks, that are mapped onto a learner development progression plan. Additionally, at the earlier stages of the programme learner inquiry tends to be more structured and evolves to more guided and even free inquiry for the oldest group of students, and this can lead to many accidental learning outcomes which is more typical of informal education.

A comparable program is run in 9 states within the United States. Denson (2015) details the Mathematics, Engineering, Science Achievement (MESA) program, an informal education environment which works with underrepresented groups to help retention in STEM. It is noted that in the MESA program the students self-identified MESA in assisting them in the following areas;

- a) informal mentoring, (b) makes learning fun, (c) time management, (d) application of math and science, (e) feelings of accomplishment, (f) builds confidence, (g) camaraderie, and (f) exposure to new opportunities.*

Science capital as a topic will be discussed later in Section 2.1.2, but Moote (2019) sees informal education as being as important part of life-long scientific literacy.

1.2.4 *Transition Year in Ireland*

Transition Year is a stand-alone programme that is offered to Irish second-level students after completing a three year Junior Cycle and prior to the beginning the two year Leaving Certificate in over 75% of schools in Ireland (Jeffers, 2011). According to the Department of Education's 'Transition Year Programme - Guidelines for Schools', Transition Year should offer the following experience:

‘A broad educational experience with a view to the attainment of increased maturity, before proceeding to further study and/or vocational preparation. It provides a bridge to help pupils make the transition from a highly-structured environment to one where they will take greater responsibility for their own learning and decision making.’ (Department of Education, 1993).

Furthermore, it should,

“Also provide an opportunity for pupils to reflect on and develop an awareness of the value of education and training in preparing them for the ever-changing demands of the adult world of work and relationships.”

The content that is offered to students during Transition Year is decided locally by the schools themselves. (Department of Education, 1993).

1.2.4.1 Mathematics

Within the Department of Education document (Department of Education, 1993), the approach taken to mathematics in the Transition Year is as important as the content itself. It should seek to stimulate the interest and enthusiasm of the pupils in identifying problems through practical activities and investigating appropriate ways of solving them. In this way, study can be brought into the realm of everyday life so that the process appears more pupil-directed than teacher-directed. The aim is to guide the pupil towards increased confidence and attainment of a more balanced view of her/his own potential for the subject.

Project Maths, a new curriculum for the teaching of Mathematics with a focus on “teach(ing) mathematics in a way that leads to real understanding” began in Ireland in September 2008. A report on its implementation said that Transition Year presented a real opportunity to

“provide innovative learning opportunities and to increase mathematics teaching hours as an important part of the strategy to develop and promote core transferable skills.” (Department of Education and Skills, 2010).

A study from Educational Research Centre conducted an analysis of teaching of mathematics in Transition Year as part of PISA 2012 (Cosgrove et al., 2012). It recommended that Transition Year mathematics could be used to increase student

engagement and build student's own confidence in mathematics. It also recommended that Transition Year be used to stress the importance of mathematics both academically with regards to mathematics requirements for third-level courses and professionally in industry. More pertinently however, it said that

"Transition Year may provide an opportunity to consolidate the mathematical knowledge and skills learned during the junior cycle, and to develop these in a manner that would act as a useful bridge to the new Leaving Certificate course. The NCCA should identify ways in which schools and teachers can align mathematics activities in Transition Year more closely with the aims of Project Maths." (Cosgrove et al, 2012).

1.2.4.2 Science Studies

The Department of Education in 1993 saw that Transition Year was a chance for students to expand their learning scope in science beyond what was in the Junior Certificate syllabus.

"an opportunity for pupils to become familiar with a broad range of Science activities. Pupils should be encouraged to study areas of Science not heretofore encountered. Topics such as astronomy, the chemical industry in Ireland, and food and agricultural suggest themselves." (Department of Education, 1993).

Aims within the document with regards to conducting investigatory work and relating science to society that is neither in the Junior or Leaving Certificate have both been usurped by newer curricula for both Junior Cycle (Department of Education and Skills, 2015) and Leaving Certificate (Department of Education and Science, 1999).

Within Transition Year there are also broad freedoms allowed to schools and teachers with regards to curriculum content. This sees a large variety of how TY science modules are organised within individual schools. Some schools will run 'taster' programmes which allow students to see what it would be like studying each of the traditional science subjects (Agricultural science, biology, chemistry and physics) at Leaving Certificate, while others will run general science modules.

As detailed previously within Section 1.2.2, there are various informal programmes which are offered to children as extra-curricular activities. The flexibility and autonomous nature of Transition Year is often used as an opportunity for students to explore these courses in a more structured and sometimes even timetabled manner. Examples of these programmes include specific STEM opportunities such as the BT Young Scientist, SciFest, The Big Idea and CANSAT, while there are others such as Green Schools and Junk Kouture which offer broader aims to students. Universities and colleges themselves often run week-long Transition Year experiences for students with the aim of offering a taste of what the college course is like by bundling applications for “*Work Experience*” into a course that is more suited for students. Examples of this would include the Transition Year Physics Experience (TYPE) within the School of Physics in Trinity College Dublin and the Minimed programme run by Royal College of Surgeons in Ireland.

A new offering for Transition Year students was then created by Trinity Walton Club in 2020 called STEM@University and it is detailed within the next section and in Section 4.

1.2.5 STEM@University

TWC was seeking to complement the existing formal learning outcomes in both Junior and Senior Cycle by developing a programme with the specific aims of improving student autonomy, self-efficacy and STEM identity. This was done in with the hope of encouraging students to study STEM subjects at Leaving Certificate level and university given the existing problems in retention of students within the discipline. Transition Year was identified as being a group that could benefit more from these specific aims and would have the time and space within their education. A decision was taken to provide complimentary and supplementary learning experiences to support students in reaching desired goals of Transition Year, especially (but not exclusively) during the time of the COVID-19 pandemic. This would not be a week-long course, but instead would be a more longitudinal programme running over 6 weeks.

A curriculum to specifically meet student needs that may not be met in the current formal education sector given what was referred to in Section 1.2.4. The theoretical basis for programme is detailed in Chapter 2 and the programme itself is described in Chapter 3.

Within the course, students were to receive college lectures from lecturers, participate in workshops facilitated by postgraduate students and work autonomously to create their own artefacts that complimented the material provided by the lecture.

1.2.6 Context of the Programme

The COVID-19 pandemic has had a profound effect on everything within our lives, and this is especially true within the field of education (Flynn et al., 2021). Within both the formal and non-formal setting, classes had to move from being face-to-face to being online within a matter of weeks as schools closed their doors from March 2020 to September 2020. This was true of my own science and physics classes, but also true of the Trinity Walton Club who had to move their club into a virtual space from March 2020 and who only have begun to resume their club activities in person in November 2021.

Educators struggled with trying to make their lessons as engaging as possible from their own kitchen. One of my main memories of this time was trying to do chromatography with my first-year science class with coffee filter paper on camera and having separated ink on my fridge for months as the pandemic went on.

This was the backdrop for STEM@University, a course that was developed to cater for Transition Year students by the Trinity Walton Club and show them what studying a STEM course in college looks like. It aimed to utilise the skills which students had gained working online during the pandemic and leverage them into development of their STEM capital, their self-efficacy in science and their autonomous learning skills.

The course was an adjunct to the Trinity Walton Club, a non-formal STEM leaning club for second level students. Trinity Walton Club was explored and explained in more detail in Section 1.2.3 but from the outset it should be stated that the course's purpose is to *"sustain and nurture student interest in science, technology, engineering and mathematics"* (Roche et al., 2016).

1.3 Perspective as a Researcher

The researcher of this study is a full-time second level teacher of science and physics in Ireland. I have eight years teaching experience with the last seven spent teaching in an all-girls school, St. Leo's College in Carlow. While gender isn't an explicit lens within this

study it is incredibly difficult to not to read study after study that relate directly to the struggles that our subject has in the recruitment of female students. These struggles are not just limited to physics but apply to recruitment of females into all areas of STEM. A report by the Department of Education and Skills (Department of Education and Skills, 2020) has commended recent progress made in this area with regards to gender but acknowledges that more work must be done. Ireland produces 24.7 STEM graduates per 1,000 males between the ages of 20-29, but only 16.6 STEM graduates per 1,000 females between the ages of 20-29. This gap is the second biggest within the EU.

Stereotypes of the ideal scientist that exist within the world of science and STEM are still perpetuated by gatekeepers and experienced by students within the modern world. Archer documented students' own stories in the United Kingdom of being told by their own teachers that successful girls in the world of physics are "*tomboyish*" in appearance or that they need a "*boy-brain*" (Archer et al., 2020). The same work by Archer documents a high attaining female physics student who felt that the hard work that she needed to exert to achieve her high grades meant that she wasn't the ideal student suited for pursuing physics at a higher level (Archer et al., 2020). In my teaching career I have seen similar students of mine choose other disciplines.

In recent years, my first class with incoming first years is a quick version of the classic Draw-A-Scientist experiment where I ask the students in my all girls to draw a scientist (Chambers, 1983). In recent years, Albert Einstein is morphing into the mad cartoon scientist Rick Sanchez, scientists have started to wear masks but I'm afraid that my anecdotal study in all-girls setting still contains 3 times as many male scientists as females. It's incredibly frustrating to see.

Having spent years challenging this in as many lessons as I can, it seems notoriously difficult to remove. The Junior Cycle years are spent with students showing them that every branch of science is an open avenue for them. Transition Year, a year which could be categorised as being non-formal, is spent openly selling my subject and challenging their preconceived notions about my subject. Leaving Certificate in my classroom is a lot of reassurance and breaking down of mental barriers among students who signed up to take what I consider to be a beautiful subject.

Completing this MSc was incredibly invaluable to me as a science teacher. The main concepts within this thesis; STEM capital, self-efficacy and motivation are things that I consider daily in my teaching as a result, but also give a new lens through which overarching schemes of work and curricula can be delivered. All too often in my job I see some of the girls I teach stressing whether they can study physics, or study higher level, or progress to studying it at third level. Society's pressure on them to not study physics is there and must be challenged and unravelled.

Getting the opportunity to work with Trinity Walton Club was fantastic. Addressing the gender imbalance was at the heart of the club but seeing the alphas (Walton Club students) thrilled to go to class every Saturday morning and hang out with their science friends is just heart-warming. My own physics journey began at the Transition Year Physics Experience (TYPE) week in the School of Physics so in a way this is coming full circle. I remember walking into the Physics Lecture Theatre in Trinity College Dublin at 16 and feeling just a sense of awe. I loved hanging out with people who were into the same stuff I liked. There was no study (to my own knowledge) conducted about the effectiveness of that week of lectures, and a visit to Armagh Observatory, but I feel that week has led to me studying physics in Trinity College Dublin as an undergraduate student and now 13 years later finishing this research.

2 Theoretical Basis

This chapter contextualises this study within the concepts of science capital, self-determination theory and how it is relevant to autonomous motivation and how Bandura's theory of self-efficacy has been used by those who wish to study where students get their self-efficacy from.

2.1 STEM Identity and STEM Capital

This section firstly discusses science identity and its relationship with science capital and introduces the concept of STEM identity capital. Instruments used to assess STEM capital are discussed.

2.1.1 Science Identity

The lens of "*Science Identity*" was formed by Carlone (2004) as a method to examine which people were promoted and marginalised within the field, to examine how students became socialised and to aid in the search for equity in the field of science education. In her work, she conceptualised that one's science identity was composed of three different dimensions, competence within the discipline, performance of those skills for people within the field and recognition both from meaningful other and from the self for the quality of those performed competencies.

What it means to be a "*Science Person*" has also been examined (Carlone & Johnson, 2007; Hazari et al., 2010, 2013) as the field comes to terms with perceptions of gatekeeping by a largely white, male field. The struggles of girls, women and people of colour have been highlighted as historical imbalances of gender and race that have yet to be corrected within the field, both nationally and internationally. (Archer et al., 2013; Carlone, 2004; Carlone & Johnson, 2007; McLoughlin et al., 2015).

In their study they reported that people saw themselves as a "*science person*" based on recognition that they received as being seen a "*science person*". This could be sourced from themselves, from people within the field and from people outside of the field that they respect. (Carlone & Johnson, 2007). This is shown in Figure 1.

Building upon this work by Carlone and Johnson, an expanded theoretical framework of a person's "*physics identity*" upon their intended choice of a physics career was studied

(Hazari et al., 2010). What shapes these identities and their relationship with performance, competence, recognition by others and a new dimension of interest was explored. Hazari explains this addition to Carlone and Johnson's framework "*Because their participants were practicing scientists, the aspect of general "interest" in science was a given for their participants. Thus, they did not include it in their model but acknowledged its importance*" (Hazari et al., 2010).

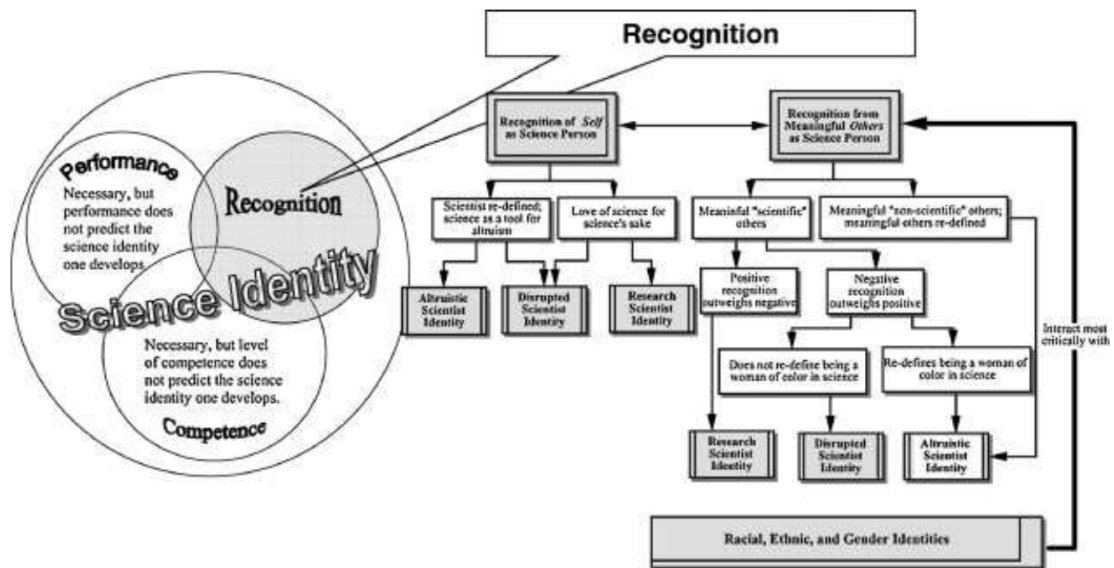


Figure 1 - Model of Science Identity (Carlone & Johnson, 2007)

Specific experiences which grew a person's physics identity were detailed using the PRiSE (Persistence Research in Science & Engineering) study which examined science attitudes amongst non-science majoring undergraduates. Hazari reported a gender disparity between males and females, with males more likely to have a higher physics identity compared to females. Hazari also suggested that high-school teachers should focus on things like conceptual understanding, making real-world connections to their work, asking students to take on the "*expert*" role, encouraging students as well as tackling stereotypes that those who pursue physics must renege on other aspects of their own lives to be successful.

Using the same PRiSE study, Hazari (Hazari et al., 2013) brought the concept of physics identity and applied it to study people's "*biology identity*" and their "*chemistry identity*", asking whether undergraduates saw themselves as a "*biology person*" or a "*chemistry person*" in the same manner as was conducted previously. While this study reported

that females were more likely to see themselves as a biology person compared to males, the difference was small in comparison to the previously reported gender disparities between males and females and their corresponding physics identities.

2.1.2 Science Capital

Bourdieu put forward a theory of cultural capital, an all-encompassing form of everything which can help a person to experience “*high culture*”. This cultural capital was something inert to everyone and contributing to it amongst other things was a person’s known number of composers, their opinions on art, what items they found to be aesthetically pleasing in photographs etc. This theory was proposed by Bourdieu alongside other forms of capital such as educational capital and economic capital (Bourdieu, 1984).

Science capital aims to encompass all the contributory factors that enable students to continue their advancement within the world of science by analysing social capital, cultural capital and their habitus (socialised, embodied dispositions) with a science specific lens (Archer et al., 2015).

The concept of science capital thus encompasses more than just science interests, attitudes or motivations – rather it comprises specific forms of science-related cultural capital and social capital, including dispositions, behaviours and social contacts, that have been previously found (ibid.) to relate strongly to the likelihood of a young person participating in post-compulsory science and espousing a science identity (that is, seeing themselves and being recognised by others as a “*science person*”) (Moote et al., 2019).

It was proposed that the index of science capital should consider student’s scientific literacy, their scientific dispositions and knowledge of how science can be used within the world of work, their consumption of scientific media, their relationships to those they know who work within the field and their own views towards themselves. The index of science capital was then developed; a 14-item instrument which measures the all-encompassing factors which contribute to a students’ science capital (Archer et al., 2015).

The specific dimensions which contribute to a persons’ science capital were then identified and labelled.

“...scientific forms of cultural capital (including scientific literacy and science dispositions, knowledge of transferability of science skills and qualifications); science related behaviours and practices (e.g. engagement with science-related media, informal science experiences), and science-related social capital (e.g. parental scientific knowledge, talking with others about science, receiving encouragement from others to continue with science).”(DeWitt et al., 2016).

Science capital is something which cannot be taught, rather it is acquired through student’s own lives given it depends upon what they consume, what they do and what they understand (Archer et al., 2015). It has been found that a student’s science capital will tend to decrease over time (Moote et al., 2019).

If someone has high scientific capital, they are someone who possesses a high amount of scientific literacy, access to science-related cultural and social resources, completes science related activities in their spare time and would be seen by their peers as being someone who is a “*science person*”. Consequently, if someone has low amounts of science capital, they would have low amounts of scientific literacy, little or no access to science-related cultural and social resources, would not be interested in completing scientific activities and would not know anyone who works in their field of science (Archer et al., 2015).

Of interest to those in third level education is that students who possess high amounts of science capital are far more likely to aspire to study a science subject at university compared to those with medium or low science capital (Archer et al., 2015; Moote et al., 2019).

The nomenclature of science capital is currently under focus both inside and outside of the ASPIRES research group. Correlations have been found within the ASPIRES project between students engineering and maths attitudes and their science capital. As a result, it has been suggested that science capital could be applied to “*SEM*” (Science, engineering and math) with further work to be explored on technology (Moote et al., 2020). Outside of the Archer group, the terms “*STEM capital*” or “*STEM capitxl*” have been used independently by researchers working on the topic (Cohen et al., 2021; Essex

& Haxton, 2018; Galaviz, 2020; McManimon & STEM Justice Research-in-Service-to-Practice Project, 2021; Plasman et al., 2021).

For the purposes of this study, the author would like to propose that the term STEM capital is used henceforth given the established links within the field. As stated previously in Section 1.2.3, TWC and its programmes are very much not just related to science alone but are built to encompass as much of STEM as possible (Prendergast et al., 2018). As you will see in Section 4.7 the STEM@University programme consists of modules that are not just scientific, but closer to STEM.

It has been found that classroom pedagogy that brings students' own ideas, knowledge, and cultural values to the fore within the science classroom can help to increase factors which would contribute to a students' STEM capital. (Archer, 2017; Nomikou et al., 2017). It is hypothesised by the author that this reflects closely of the experience felt by students' in TWC.

To those already within informal science education, science capital has been used to investigate both what draws people to their sites, but also in how they engage within them. Not only are those people who possess high amounts of STEM capital more likely to visit their cultural sites, but has been found that visitors to an historic visitor site that possessed higher amounts of science capital exhibited more engagement with museum content (Archer et al., 2015; Essex & Haxton, 2018). Changes in students STEM capital have been observed after students attended a one week community zoo and an after school STEM club which took place over 5 months (Archer et al., 2021). The point has been made that the UK formal education system is failing to provide students with scientific cultural capital (Moote et al., 2019) and as a result there is a need for these cultural spaces to exist within society to provide opportunities for growth.

While the lens of social justice is one which will not be used within this research, many are now using STEM capital as a lens that can cast an eye on what groups are underrepresented within STEM, why this happens, and what can be done about it? (Archer et al., 2021; Cohen et al., 2021; McManimon & STEM Justice Research-in-Service-to-Practice Project, 2021; Moote et al., 2019). Archer (2021) states that *"Our Bourdieusian lens thus explains how youth are Othered and made to feel out of place in*

many ISL settings due to a disjuncture between habitus and field and because the field is set up to further the interests of the dominant.” That is those with high STEM capital possess the capital and dispositions to thrive, and this is enabled by the those who control the STEM setting.

This is problematic as described earlier, it’s been found that boys will possess higher amounts of STEM capital compared to girls and that the gap between them increases with age (Moote et al., 2019). Those who could be described as having high amounts of STEM capital are more likely to come from homes that are socially advantaged, while those who possess low amounts of STEM capital are more likely to come from homes that are socially disadvantaged. The interplay between STEM capital, STEM identity and STEM identity capital has also been modelled and hypothesised (Cohen et al., 2021). This will be further discussed within Section 2.1.3.

2.1.3 STEM Identity Capital

Since the inception of science capital, the links between science identity and being a “*science person*” have been important. Archer developed science capital using science identity as a yardstick drawing on the work of Carlone and Johnson (2007). They consequently found that students who possessed high amounts of STEM capital are more likely to consider themselves as a “*science person*” (Archer et al., 2015). Those who possess the capital are indeed secure in their identity.

Recently, the relationship between STEM capital, STEM identity and another variable called STEM identity capital has been explored and this is shown in Figure 2 (Cohen et al., 2021). It is described as a specific form of capital which is used to develop and maintain STEM capital and acquiring it initially could be found in specific significant early years STEM experiences. It was found that in early encouragement in STEM from primary school teachers, using STEM toys/kits, watching STEM related television shows, playing STEM related video games, and observing astronomical objects contributed significantly towards building a positive STEM identity while kitchen chemistry and writing about STEM contributed negatively towards it.

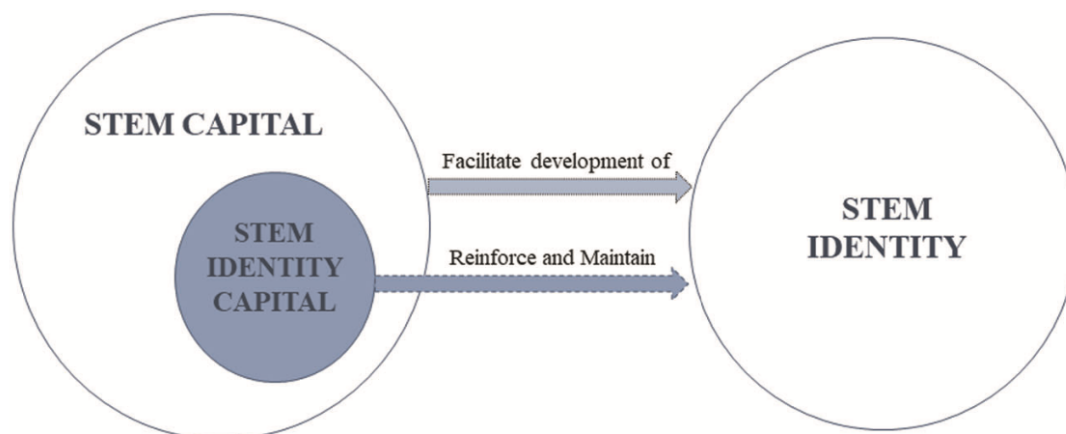


Figure 2 - Model of STEM Capital/Identity/Identity Capital (Cohen et al., 2021)

For a programme like STEM@University, it is hypothesised that student participation would increase student STEM identity (Calabrese Barton & Tan, 2010). However, it would be desirable to identify specific elements that could be included so that the student would have the opportunity to maximise their STEM identity development.

Within the framework described, this study will aim to develop three contributing factors to a student's STEM Identity.

- STEM Capital

Carlone (2004) reported a conflict between students science identity and their “*good student identity*” within the formal classroom. It could be hoped that when students are removed from the formal classroom that they have more freedom to explore and express their own science identity within a more comfortable environment. As shown in Figure 2, by aiding the development of capital, it is hypothesised that the programme would also be aiding the development of STEM identity.

- Self-Efficacy

Students who perceive themselves to have lower amounts of science ability have been shown to not be comfortable to create new meanings which could threaten the dominant science identities within the formal classroom (Carlone, 2004). A similar finding was noted where one’s science identity was linked to the perception of the “*good science student*” who finds completing science problems to be easy (Jackson & Seiler, 2013). Self-Efficacy has explicitly been linked to a student’s STEM capital

development (Archer et al., 2015) and to STEM identity development (Cohen et al., 2021).

- Autonomy and Motivation

Intrinsic motivation has been identified as being an important part of recognition of one's self and abilities (Carlone & Johnson, 2007). When discussing this topic specifically in relation to physics, a deep fulfilment has been described between the physicist and their acquisition of knowledge, skills and products (Hazari et al., 2010). While this inner drive has been associated with better physics outcomes for the student, it has also been suggested that the physics community needs to counter the narrative in order to be a "*good physicist*", one must sacrifice other goals that they have in life (Hazari et al., 2010).

2.1.4 Towards a Non-Formal STEM Experience

The word "*experience*" is often used to describe a learning environment which is situated outside of the formal education sector, particularly within the informal sector but also within the non-formal sector (Archer et al., 2016; Cohen et al., 2021; Dou et al., 2019; Popovic & Lederman, 2015; Post & Walma van der Molen, 2018; Roberts et al., 2018; Roche et al., 2019). It could be described as a structured STEM learning environment outside of the classroom. The benefits of both non-formal and informal STEM environments have already been described in Section 1.2.2. A literature review on non-formal STEM learning experiences stated that the learner tends to have large amounts of control over varying factors within a non-formal STEM experience (Roche et al., 2019). They often get to choose not only what to learn and how to learn; but also factors such as when to learn and how much to learn. Non-formal educational experiences are typically unassessed unless it is to gain insight as to the effectiveness of the programme. Facilitators are trained to encourage critical thinking, science exploration and reflection.

2.1.5 Measuring STEM Capital

The index of science capital was created by Archer et al. (2015) and contained 14 items "*that most closely related to a dependent measure of future science affinity and science*

identity.” (Moote et al., 2020). As detailed in Section 3.4.1, the index is composed of items to evaluate student’s scientific literacy, their scientific dispositions and knowledge of how science can be used within the world of work, their consumption of scientific media, their relationships to those they know who work within the field and their own views towards themselves. Weightings for each item are detailed within Moote et al., (2019, 2020).

Changes in STEM capital also were measured qualitatively by coding of statements by participants in an informal science learning setting (Archer et al., 2021, p. 202).

A proxy value of science capital has been approximated from PISA2015 data and this allowed the authors to compare the science capital of the students between two countries (Du & Wong, 2019).

A 25 item multiple choice questionnaire has also been developed to measure science capital with reference to the ASPIRES instrument (Canovan & Walsh, 2020).

It was decided to measure the student’s STEM Capital quantitatively using the index of science capital (Moote et al., 2019, 2020). The advantages of using this instrument included that it was publicly accessible, credibly reliable within the field, short enough to be contained within a larger questionnaire and allowed us to compare our population to that contained within previous studies (Archer et al., 2015; Moote et al., 2019).

2.2 Self-Efficacy

This section defines self-efficacy, where it is derived from and how it is relevant to educators across all subjects but especially within the field of STEM education.

2.2.1 What is Self-Efficacy?

The psychologist Bandura has defined self-efficacy as one’s own beliefs as to how well one can complete a given task (Bandura, 1982). It has also been written that performance within multiple domains is driven largely by participants’ own belief systems (Bandura, 1997). To perform effectively, one must not only possess the skills to succeed, but also believe that they can apply their skills well.

Bandura states that “*Efficacy beliefs are the product of cognitive processing of diverse sources of efficacy information conveyed enactively, vicariously, socially and physiologically*”. (Bandura, 1997, p. 115). Bandura (1997, p. 79) proposed four sources of self-efficacy, namely:

- Mastery experiences
- Vicarious experiences
- Verbal persuasion
- Physiological and affective states

Mastery experiences are described as the most influential and authentic of the sources of self-efficacy. In gaining self-efficacy through mastery experiences, one must go through a period of difficulty and struggle. “*A resilient sense of efficacy requires experience in overcoming obstacles through perseverant effort*” (Bandura, 1997, p80). After going through this period of strife, one knows that they have the skills and capabilities to overcome adversity and that they will come out of this task not only successful, but with added capabilities for the next challenge (Bandura, 1997).

When one’s proficiency is judged in relation to the performance of others, social comparison acts as the main guiding factor in your own self-judgement. This is self-efficacy gained through vicarious experiences (Bandura, 1997, p. 87). People will compare and judge themselves based on the own skills in relation to their workers, their classmates and their friends and place themselves in a relative standing amongst who they know. Performances surpassing the norm results in higher self-efficacy beliefs while those below the mean will result in lower self-efficacy beliefs (Bandura, 1997).

When doubts creep into oneself in relation to their own capabilities, a reassurance from a significant other can have a sustaining effect on one’s self-efficacy. This is verbal persuasion (Sometimes labelled as social persuasion) (Bandura, 1997, p. 101). Bandura (1997) hypothesises that it’s power may be limited in its power to create long lasting increases in self-efficacy, but it can strengthen self-change if the praise is realistic in nature. It is described by Bandura (1997, p. 106) as being a “*useful adjunct to more powerful efficacy-promoting influences*”. Bandura writes that a good builder of self-

efficacy in others will not only tell them about their efficacy, but also provide them with the exercises, activities, and environment for one to build their self-efficacy themselves.

People often become aware of their self-efficacy sourced from physiological and affective states because of stress, anxiety, dread, and feelings of ineptitude in relation to a specific task. Bandura (1997, p. 106) writes that these feelings are not only limited to stress but also to fatigue, aches, and pains as feelings of physical inadequacy in completing a given task.

2.2.2 Self-Efficacy in Education

The effects of the benefits of increasing amounts of self-efficacy have been summarised both by Bandura (1997, p. 214) and by Pajares (2002). They state that self-efficacy beliefs can influence the choices that people make as they will tend to do things that they consider themselves to be proficient in. People will also tend to put increasing amounts of effort, increasing amount of perseverance and resilience into those same tasks. Finally, self-efficacy beliefs can influence the stress and anxiety levels which people will feel as they engage with a task. With higher levels of self-efficacy, tasks become challenges to be conquered rather than something to be feared. Higher levels of self-efficacy are also linked with better performance in examinations, deeper learning within subjects, and negatively correlates as a measure of anxiety experienced by students within subjects (Pajares & Kranzler, 1995). Higher levels of self-efficacy increasing deep learning in learning within science has also been reported (Lin & Tsai, 2013).

Miserandino (1996) has linked self-efficacy to feelings of competence and performance for children as young as 3rd and 4th grade in elementary school. Mental health and self-efficacy within adolescents have also been correlated and studied. It has been found that students with low amounts of self-efficacy are more likely to not be confident socially, not assert themselves and consequently are more likely to feel lonely or withdrawn (Parto, 2011).

It has also been reported that self-efficacy is a strong predictor of both mathematics performance and mathematics anxiety (Pajares & Kranzler, 1995). A link has also been established between an individual's higher feelings of self-efficacy in STEM to their

likelihood to pursue a STEM subject after second level education in the Netherlands (van Aalderen-Smeets et al., 2019). A direct link has been posited between science student's feelings of competence and their intention to pursue a science course in third-level education (Lavigne et al., 2007).

Student's self-efficacy within science, mathematics and engineering can be improved from experiences of mastery (Britner & Pajares, 2006; Usher & Pajares, 2009). They interpret mastery in the school context to be

"When students believe that their efforts have been successful, their confidence to successfully accomplish similar or related tasks in the future is raised; when they believe that their efforts failed to produce the effect desired, confidence to succeed in similar endeavours is diminished." (Usher & Pajares, 2009).

Specifically, within the field of science education, Britner and Pajares (2006) have correlated middle school students' science self-efficacy with their mastery experiences, vicarious experiences, social persuasions, physiological arousal, and overall self-efficacy.

A difference was also recorded in how self-efficacy could be developed within girls by use of appropriate social persuasion.

"...the academic self-efficacy beliefs of girls may be more strongly informed by the messages they receive from teachers and from adult family members and significant others than from their actual academic accomplishments". (Britner & Pajares, 2006).

It has been reported that students with higher amounts of science self-efficacy are more likely to possess higher amounts of science capital (Archer et al., 2015). Ito and McPherson (2018) have examined self-efficacy within pSTEM (Physical science, technology, engineering and mathematics) environments and have found that female students will exhibit less self-efficacy than their male counterparts. This study correlated students' self-efficacy with social belonging, correlating self-efficacy with intentions to continue studying within the field of pSTEM.

Of note is also that increasing academic achievement in college engineering students has been linked to higher amounts of self-efficacy sourced from mastery experiences (Loo & Choy, 2013).

2.2.3 Measuring the Opportunity to Enhance Self-Efficacy

There are many different and validated tools used to measure self-efficacy among students, and it must be decided whether this research seeks to evaluate self-efficacy itself or the sources of self-efficacy.

One such approach is to construct a self-efficacy scale in line with pre-existing guidelines (Bandura, 2006). This method would involve asking students questions to respond on a 0-100 scale to questions like *“How confident would you be in achieving an A in Science this term?”* and repeating the same question for a B grade, C grade and so on. This method has been used to directly measure self-efficacy in both science and mathematics (Britner & Pajares, 2006; J. A. Chen & Usher, 2013). Adopting such an approach in this study was considered problematic as the students are in Transition Year. As detailed in Section 1.2.4, student development and curricula during Transition Year are not solely focused on grades and teacher feedback given to students might not necessarily be about the acquisition of improved grades. As a result, students’ own estimation of what grades they will achieve may not be a reliable indicator of their self-efficacy.

In the work of the ASPIRES project relating to science capital, three items in the questionnaire were given to the students. *“I am confident giving answers in science lessons; I know quite a lot about science; I don’t think I am clever enough to study any of the sciences at A-level.”*(Archer et al., 2015).

Self-efficacy in mathematics has been measured by way of a variant of Dowling’s mathematics confidence scale (Pajares & Kranzler, 1995). This is an 18-item scale which asks students to solve mathematics problems equally across three different strands of mathematics, (Arithmetic, algebra and geometry) across three different levels of cognitive demand (Computation, comprehension and application) and also finally in both real and abstract applications. When constructing and validating their sources of mathematics self-efficacy scale (which will be discussed later) mathematics self-efficacy

was measured using four different Likert scale instruments; mathematics grade self-efficacy, mathematics courses self-efficacy, mathematics skills self-efficacy and self-efficacy for self-regulated learning (Usher & Pajares, 2009).

The sources of mathematics self-efficacy scale was developed by Lent et al. (1996). In it there are four different subscales to measure the effect of mastery experiences, vicarious experiences, social persuasions, and physiological states. It was adapted for use subsequently by Usher and Pajares (2009) and the adapted instrument for science is discussed in a later section and is presented in the appendix of this document. Usher and Pajares' sources of mathematics self-efficacy scale was used to investigate sources of science self-efficacy (Chen & Usher, 2013), likewise this is discussed in further detail in the next section.

An instrument called the science learning self-efficacy scale was developed to measure different dimensions of self-efficacy. This aimed to capture the science self-efficacy of 8th graders under the headings of conceptual understanding, higher-order cognitive skills, practical work, everyday application, and science communication (Lin & Tsai, 2013). This instrument was considered for use by the author, but it wasn't selected as it was not validated on a large scale, not validated in different age groups apart from 8th graders, and there also was a possibility of there being language and translation issues with an English language instrument given it was initially presented to children in Chinese.

A decision must be made in this study whether self-efficacy is directly measured or if it is preferable to assess the sources of self-efficacy. As self-efficacy is derived from the individual cognitively processing information from the four sources of self-efficacy (Mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states). This is detailed in Section 3.4.3.

2.3 Autonomy

This section outlines Self-Determination Theory and how it is relevant to student autonomy. The benefits of being autonomously motivated are stated, in both the context of STEM and online courses. Differences are described between intrinsic and

extrinsic motivation as well as methods to assess whether students are extrinsically or intrinsically motivated.

2.3.1 Self-Determination Theory

Self Determination Theory developed by Ryan and Deci (2000b) deals with motivation, both in its strength and its source. It seeks to differentiate the differences in motivation between internal and external sources, e.g. Does a student want to create a higher quality artefact at STEM@University because it interests them, or because they will get in trouble if they do not? It is a lens through which this study will be examining autonomy and motivation at STEM@University.

It postulates that there are three innate psychological needs that when thwarted lead to diminished well-being and motivation, but when satisfied lead to increased amounts of self-motivation and increased mental health. The three needs, competency, autonomy and relatedness are important to the self and if fulfilled lead to different and better quality levels of motivation within the self (Ryan & Deci, 2000a).

As a result, according to Self-Determination Theory, it's important to put in place the environment in STEM@University that is conducive to facilitating these needs. It is desired that students have high levels of self-motivation and for them to be in an environment that is *"antagonistic to the tendencies"* (Ryan & Deci, 2000a). Ryan and Deci state that Self-Determination Theory allows them to specify these conditions under which *"natural activity and constructiveness will flourish"* (Ryan & Deci, 2000a).

2.3.2 The Nature of Motivation

"The most basic distinction is between intrinsic motivation, which refers to doing something because it is inherently interesting or enjoyable, and extrinsic motivation, which refers to doing something because it leads to a separable outcome." (Ryan & Deci, 2000b).

At the heart of Self-Determination Theory is the belief that it is preferred when a person is doing something for fun, for the challenge or for their own personal desires. Doing something that interests you is preferable doing something as that doesn't; it fulfils and is enabled by deep psychological needs. This contrasts with doing something that is for one of varying degrees and inputs of external pressure. Does a student do an activity

because they are curious, they will get a reward or because will they get in trouble if they do not do so? *“Even superficial reflection suggests that people are moved to act by varying factors”* according to Ryan and Deci (Ryan & Deci, 2000a).

If one’s own motivation is *“authentic”*, one can expect that their corresponding action will have more interest, excitement, and confidence in completing the task, which in turn will lead to greater levels of performance, persistence, and creativity, as well as vitality, well-being and self-esteem. (Ryan & Deci, 2000a). *“Perhaps no single phenomenon reflects the positive potential of human nature as much as intrinsic motivation”* (Ryan & Deci, 2000a). Tasks completed when the individual is intrinsically motivated will result in more active learning and higher amounts of conceptual understanding (Benware & Deci, 1984).

The effects of fostering intrinsic motivation within the academic context have also been noted and studied (Miserandino, 1996; Lavigne et al., 2007; León et al., 2015; Salmi & Thuneberg, 2019).

Miserandino (1996) reported that children who reported experiencing autonomy during school acted *“more involved, participating, and persisted more at tasks while in school and experienced curiosity while doing so.”* STEM students were provided with the supports that facilitated autonomy in line with Self-Determination Theory (León et al., 2015). They were given choices in both instruction and in assessment. Leon found that this autonomous motivation saw that students were more likely to engage in deep processing. These specific supports will be discussed in more detail in the next section. A visit to a science museum which was studied saw that students with higher levels of autonomy (and thus intrinsic motivation) had better overall science knowledge and gained more knowledge specific to the science museum visit (Salmi & Thuneberg, 2019). A model validated by Lavigne, Vallerand and Miquellon (Lavigne et al., 2007) saw that students with perceived higher levels of autonomy had more motivation in studying science and better persistence within the subject.

Extrinsic motivation refers to the completion of an action or task to obtain a separable outcome. There are differing types of extrinsic motivation that where one’s autonomy can vary, for example completing an artefact for STEM@University because you can see

the value of completing it or doing it because one's parents are making them complete it (Ryan & Deci, 2000a).

An incentive to complete a task would be classified as an extrinsic motivator. These incentives can be financial, prizes, credits, promotions, grades, awards, health benefits, praise, and recognition are all incentives. Indeed, it has been discussed that grades themselves would be an incentive and thus, a source of extrinsic motivation. Offering incentives to complete tasks has been described as "*The Undermining Effect*", where the reward for task completion takes away from intrinsic motivation. Why would someone need to incentivise this if it was worth doing in the first place? (Cerasoli et al., 2014).

2.3.3 Fostering Autonomy in line with Self-Determination Theory

Autonomy has been seen as being a desirable trait by many different academics over a long period of time, and indeed has been identified as a desired skill to be developed among Irish university physics students (McCauley & McClelland, 2004). It is said to be one of three needs that one needs to be satisfied to achieve a sense of self-fulfilment (Deci & Flaste, 1996). Being intrinsically motivated to do something, while being something that one is born with, is something that must be maintained and enhanced by being within an environment that is conducive to facilitating it as one grows (Ryan & Deci, 2000a).

It is highly important that in a course like STEM@University, that students are sufficiently autonomously motivated to participate. Deci and Flaste stated that "*Providing choice, in the broad sense of that term, is a central feature in supporting a person's autonomy*" (Deci & Flaste, 1996). Indeed, it is written that choice, acknowledgement of feelings and opportunities for self-direction allow increased levels of autonomy and thus increased levels of intrinsic motivation (Deci and Ryan, 1985 as cited in Ryan & Deci, 2000a). The finding of choice helping to provide intrinsic motivation and autonomy has been verified in a meta-analysis (Patall et al., 2008). The conditions of choice, acknowledgement of feelings, and opportunities for self-direction, aren't a cause of intrinsic motivation, rather they cause almost an awakening from within the self of the natural instincts that everybody possesses. The opposite is also true, where conditions that are not conducive to intrinsic motivation are those that dull

these innate properties (Ryan & Deci, 2000a). Deci and Ryan themselves state that external methods of force or coercion such as *“tangible rewards ..., threats, deadlines, directives, pressurised evaluations and imposed goals”* are not methods to facilitate intrinsic motivation (Ryan & Deci, 2000a).

Within Self-Determination Theory, it is said that *“social-contextual”* events can increase feelings of competence that would feed into higher levels of intrinsic motivation. These events are said to be times of feedback, communication, and rewards. Moreover, *“Optimal challenges, effectance promoting feedback and freedom from demeaning evaluations”* were also found to be enablers of intrinsic motivation (Ryan & Deci, 2000a). Competence alone however is not enough in order to increase intrinsic motivation; it must be accompanied by autonomy as people must experience their own actions and behaviour as being self-determined (Ryan & Deci, 2000a).

The interplay between autonomy supporting and autonomy thwarting practices in the high school STEM classroom has been studied and reported on (Patall et al., 2018). A diary study of teaching practices and student perceptions found that students were able to perceive accurately strategies and practices which were meant to increase their autonomy, but they perceived autonomy thwarting strategies as their teacher providing structure and support. Student supports which increased autonomous motivation included choice provision, consideration for student preferences and interests, rationales for importance, and question opportunities. It was found that uninteresting activities decreased student autonomous motivation.

The impact of specific STEM activities offered by universities for students was studied in both USA and the Netherlands (Vennix et al., 2018). They found that outreach research activities could increase autonomous motivation if they were found to be personally relevant to the student and thus increased their needs fulfilment. The author acknowledges that while the STEM@University isn't an outreach STEM activity, it has similar aims to the study described.

Stefanaou et al. (2013) writes about ways that students can be encouraged to make decisions and take ownership of their own learning. They categorise different strategies to support autonomy into organisational, procedural, and cognitive.

A framework for the fostering of learner autonomy within Massive Open Online Courses (MOOCs) through the lens of Self-Determination Theory was developed and tested (Martin et al., 2018). It was found that putting in place the structures to satisfy basic psychological needs helped to retain learners throughout their online course. More specifically with regards to fostering autonomy it is important that the course

- “
- *offers meaningful choice;*
 - *allows self-paced learning and sets no deadlines;*
 - *limits task imposition and reward contingencies; and*
 - *provides task involvement, immersion, and a sense of presence.”*
- (Martin, Kelly and Terry, 2018).

Similar guidelines to this were published (Lee et al., 2015) who together suggested that in online student autonomy and thus engagement could be grown by offering choices in assignments, providing rationale for decisions and opportunities for personalisation. This is echoed in guidelines for teachers which stated that providing choice opportunities, providing rationales, and incorporating student perspectives are desirable for building student autonomy within the classroom (Patall & Zambrano, 2019).

MOOCs were examined through the lens of self-regulated learning. In this study, they wanted put structures in place to “*successfully deal with the autonomy in online education*”, seeing it as a barrier to be overcome for the learner. They found that by engaging learners in phase of preparation, action, and reflection throughout the course that it had a positive impact on course completion (Jansen et al., 2020).

2.3.4 Measuring Autonomy and the SRQ-A

The instrument selected for assessing student autonomy was the Self-Regulated Questionnaire – Academic (SRQ-A) (Connell & Ryan, 1989) and this is discussed in Section 3.4.5. Other instruments considered included the situational motivation scale (SIMS), the academic motivation scale (AMS) and the self-regulated questionnaire-learning all which was also developed in line with Self-Determination Theory

The SIMS instrument measures a snapshot of motivation in a given situation at a particular time and space while completing a specific task (Guay et al., 2000). The AMS instrument provides more detail on intrinsic motivation, but for our purposes the items within the SRQ-A are more closely tied to the school environment, and thus the SRQ-A was chosen (Vallerand et al., 1989).

3 Methodology

This chapter will begin by detailing the research questions that guided this master's research, as well as the methods that were used to address them. This study undertakes a mixed-methods approach, as this study looks at the three differing quantitative instruments as well as using qualitative research. The data was collected between March and June of 2021.

3.1 Research Questions

The aim of this study was to evaluate the students' experiences of STEM@University, through measuring learner development against desired outcomes. This study addresses the following research questions:

1. What *were* the transition year students experiences of the STEM@University programme?
 - a. Did their experience reflect the desired goal of the programme?
 - b. What are the recommendations for improving student experiences of STEM@University?
2. Does the STEM@University programme contribute to the enhancement and/or development of transition year students:
 - a. STEM Capital,
 - b. Self-Efficacy,
 - c. Autonomy,
 - d. STEM Identity.

To answer the above research questions, a mixed-methods approach was selected.

As discussed within Sections 2.1.5, 2.2.3, and 2.3.4 a range of both quantitative and qualitative instruments and methods have been used to measure STEM capital, autonomy and self-efficacy. This will be further expanded upon in Section 3.

The use of mixed methods in this research will allow us to take advantages of both quantitative and qualitative methods and allow us to validate and contrast the differing results presented by both techniques.

Ethical approval for this research was granted by the Ethics Committee of the School of Education in Trinity College Dublin.

3.2 Participant Selection

After signing up to participate in the in module 2 and module 3, students were invited to participate with both their own and parental consent. Anonymity within the course was conserved by use of a unique identifier (Yurek et al., 2008). The use of this unique identifier allows Pre and Post Questionnaires to be matched, as well as reflection sheets and artefacts.

Once a student agreed to participate in the course, the researcher emailed them the links to the questionnaires, as well as invitations to participate in the focus group.

49 students in total agreed to participate in the study, however 29 students completed pre- questionnaires and 16 completing post-questionnaires.

3.3 Data Collection

3.3.1 Focus Groups

The structure of the focus groups was planned in accordance with guidance from Gibson (2007) but given the collection of data took place during the COVID-19 pandemic, it took place online using Microsoft Teams. The use of focus groups to examine STEM topics using children has been used successfully online using children has been shown to be reliable (Bruce-Davis et al., 2014).

Focus groups were to be structured to have between 6-8 participants and take place for a duration of between 45 minutes to 60 minutes. The focus groups were to be scheduled to take place as close to the end of the course as possible while also taking place before schools broke up for the Summer. They were also scheduled to take place during school hours to account for fatigue that may be experienced by children if the focus group were to appear after school (Gibson, 2007).

3.3.2 Questions and Exercises within the Focus Group

Question and exercise selection during focus groups is incredibly important. The use of activities and exercises can be used to maintain concentration, focus attention, and elicit discussion that may have otherwise been left undiscovered if left to traditional

questioning alone (Colucci, 2007; Gibson, 2007). The use of activities is said to be an important tool especially in focus groups containing young people as they

“...can become bored after a sequence of verbal questions and start losing attention and also tend to act out and express their feelings and ideas in more active ways than adults.” (Colucci, 2007)

Colucci (2007) details activities can stimulate discussion and provide the basis for the facilitator to probe for more descriptive answers and reasoning.

Similar studies have been conducted among students where students were asked in focus groups about their STEM attitudes and experiences, both within the formal, non-formal and informal environments. These were helpful in guiding the appropriate register of questioning that was deemed necessary to elicit the desired responses from learners (Denson et al., 2015; Holmegaard et al., 2014; S. Lou et al., 2009; S.-J. Lou et al., 2011).

3.3.3 Focus Group Prompts

Prompts were developed to explore the results within the three chosen instruments and provide appropriate qualitative background to the results contained within it. One prompt was chosen to accompany each instrument; probing the development of STEM capital, self-efficacy, and autonomy with additional time for the participants to add in aspects of STEM@University that they wished to discuss themselves. These are detailed in Section 3.4.2, Section 3.4.4, and Section 3.4.6 respectively.

3.4 Data Analysis

3.4.1 Quantitatively Assessing Changes in STEM Capital

For research question 2, it was desired to see if student's own identification and habitus within science and STEM changed during their time at STEM@University. To do this, an evaluation of the existing instruments and methods employed by researchers to measure STEM capital were evaluated.

It was decided to measure the student's STEM capital quantitatively using the index of science capital with the question weightings as described (Moote et al., 2019, 2020) and

as referenced in Section 3.4.1. The advantages of using this instrument included that it was publicly accessible, credible within the field, short enough to be contained within a larger questionnaire and allowed us to compare our population to that contained within previous studies (Archer et al., 2015; Moote et al., 2019).

3.4.2 Qualitatively Assessing Changes in STEM Capital

Students were asked the following prompt to ascertain their feelings with regards to their own STEM capital development during STEM@University.

“Can you see yourself doing anything different in the immediate future because of participating in STEM@UNI?”

“Can you see yourself doing anything different in the distant future because of participating in STEM@UNI?”

Previous links have been made between a student’s science capital and their “Post-18” aspirations (Archer et al., 2015). These prompts were developed to get students to discuss openly what, if anything, may have changed about their own personal aspirations, both this year and after their time in secondary school. Transition Year is a time when secondary school students are empowered with choices in their learning as they will be selecting their subjects for study at the Leaving Certificate level. Factors such as liking the subject and whether students see it important for their own learning come into focus when students are selecting their subjects for the Leaving Certificate (Smyth & Calvert, 2011). Female students in Ireland particularly report concerns about their own self-efficacy when it comes to physics, and parents feel that having a clear and defined career path is important for their daughters (McLoughlin et al., 2015).

3.4.3 Quantitatively Assessing Sources of Science Self-Efficacy

To quantitatively measure changes in science self-efficacy a 24-item scale, developed by Usher and Pajares (2009) for mathematics was selected and included in the pre and post survey. The prompts were adapted for use in a science context by substituting the word *mathematics* with *science*. For example, “*I get depressed when I think about learning math*” became “*I get depressed when I think about science*”. This study was adapted in a similar manner for use in science (J. A. Chen & Usher, 2013). Chen and

Usher substituted 3 items in for Vicarious Experiences, but didn't mention which ones they replaced, as a result the adapted 2009 scale was used.

The instrument aims to measure the four contributing aspects to a student's scientific self-efficacy as defined by Bandura (1997) by asking six questions on each aspect of

- Mastery experiences
- Vicarious experiences
- Verbal persuasion
- Physiological and affective states

This scale was most suitable as this study wanted to see where any self-efficacy changes during students' time at STEM@University came from given this programme would be different to what students would be experiencing day to day in their formal education environments. Using the sources of science self-efficacy scale allows multiple advantages over directly measuring self-efficacy scale as outlined by Bandura (2006). Firstly, it removed the dependence on relating self-efficacy to grades achievable within the formal education system which may have been troublesome for us given our sample group was Transition Year students. Secondly, using the sources of science self-efficacy scale allowed us to see if the programme provided opportunities for self-efficacy shift to the students to each of the four aspects. This not only allows us to note the effect of specific aspects of the course, but also should remove the individual students' cognitive processing from the process (J. A. Chen & Usher, 2013).

3.4.4 Qualitatively Assessing Self-Efficacy Opportunities

When deciding on a prompt to elicit student's own feelings towards self-efficacy, it was appropriate to pick a question which gave students the comfort and freedom to discuss the course. While it was previously noted that some self-efficacy questionnaires ask this by asking students to predict their grade (Bandura, 2006) this might have been appropriate in the focus group environment along with all the previous measures that were discussed in the methodology section for the quantitative instrument. Trujillo and Tanner (2014) used the word "comfort" in varying different questionnaire items to ascertain student's own sense of belonging within STEM. Comfort was therefore chosen as an age-appropriate version of describing self-efficacy to participants as it would be

associated with feelings of anxiety and stress in line with questions contained in the sources of science self-efficacy instrument.

After this, following prompt was developed:

“Did participating in STEM@University make you feel more or less comfortable with STEM?”.

Further probing into the specifics of this was done by asking them:

“How did this happen during the course?”.

3.4.5 Quantitatively Assessing Autonomy

The instrument chosen to measure student autonomy in this study was the Self-Regulated Questionnaire – Academic (Connell & Ryan, 1989). It measures student motivation and regulation along four different subscales

- External regulation
- Introjected regulation
- Identified regulation
- Intrinsic motivation

This instrument has been used often to measure student autonomy, including student autonomy within STEM environments (Kroes, 2021; Patall et al., 2018; Rajapakse Mohottige, 2016; Salmi & Thuneberg, 2019) and in Irish post-primary students (Sisamakias, 2006) and elsewhere (Fadilah et al., 2019). Its reliability has been established and validated many times over. While it was designed for children as young as primary level, it has been used at post-primary level. The questionnaire for self-regulated learning in adults (SRQ-L) which is referenced within the SRQ-A itself was it was deemed by the author not to be relevant to children in a school environment.

The relative autonomy index (RAI) is a score which uses the SRQ-A to indicate whether a student is overall extrinsically motivated, or intrinsically motivated. Where a negative overall score indicates that a student is extrinsically motivated, and a positive overall score indicates that a student is intrinsically motivated. The more negative the score, the more extrinsically motivated the student is, and the more positive the score the more intrinsically motivated the student is.

The RAI is calculated by the following formula;

$$RAI = 2(Intrinsic) + Identified - Introjected - 2(External)$$

3.4.6 Qualitatively Assessing Autonomy

To prompt for autonomy, the following open ended free-listing prompt was selected.

“What do you feel you developed over your time at STEM@University compared to your time in TY?”

Further actions to elicit additional response and stimulate conversation were such that participants were to be asked:

“How did you do this in STEM@University?”

After asking the students to participate in the free-listing and subsequent description, students were to participate in a ranking activity, where they were provided with the answers that they had previously given themselves and asked to rank them giving higher priority to skills and attributes that developed the most during their time at STEM@University.

If participants did not independently identify autonomy as something which was developed over the course, the facilitator was to ask a further prompt, where students would be asked to insert autonomy into their rankings and explain their reasoning.

4 STEM@University Programme

This section will detail the STEM@University programme.

The course intentions will first be discussed. It will be placed within the context of the science learning that students have done so far and the decisions that they will have to make in the future. The pedagogy of each specific module will be described.

While the theoretical basis for STEM identity development within STEM Capital, autonomy and self-efficacy has already been outlined, this chapter will elaborate further on aspects of course design that the programme should be cognisant of. Specifically, as a STEM course, an online course and a course that is making use of student reflection as an assessment tool. Throughout this, the STEM@University programme will be compared to the desired characteristics for a learning environment of this nature.

4.1 STEM@University Programme

The STEM@University programme was designed to provide an out of school, scaffolded educational experience for TY students at a time when they are moving from a highly structured junior cycle environment into their senior cycle. Each module was designed to be a 6-week long experience and the elements to the structure presented in in Figure 3.

Table 1 shows further information related to the level of student participation throughout the 6 week long experience, learner tasks and approximate time commitment. The calendar of a STEM@University module is shown in Figure 4. Students completed modules in STEM@University as presented in Table 2.

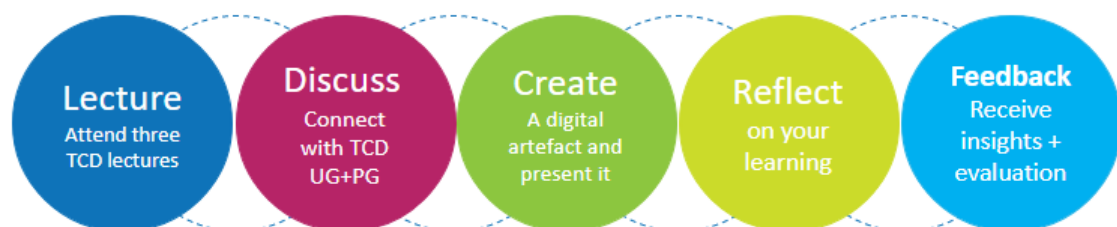


Figure 3 - STEM@University Programme Elements

STEM@University was designed to complement the existing learning goals of the Transition Year programme. As seen in Section 1.2.4, Transition Year is an important time for students. They have completed all aspects of their Junior Cycle science education and are considering what academic path to continue; in the short term they will make decisions with regards to their Senior Cycle subject choice which in the medium term can shape their third level academic choice and in the long term their career paths.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
25 Jan	26 Jan	27 Jan	28 Jan	29 Jan	30 Jan	31 Jan
	Powers of 10 Lecture Link Delivered		Powers of 10 Live Webinar 4.30pm	Powers of 10 Artefact Creation		
1 Feb	2 Feb	3 Feb	4 Feb	5 Feb	6 Feb	7 Feb
artefact due			Artefact Assessment Live Webinar 4.30pm			
8 Feb	9 Feb	10 Feb	11 Feb	12 Feb	13 Feb	14 Feb
	Anatomy of Dynamic Planet Lecture Link Delivered		Anatomy of Dynamic Planet Live Webinar 4.30pm	Anatomy of a Dynamic Planet Artefact Creation		
15 Feb	16 Feb	17 Feb	18 Feb	19 Feb	20 Feb	21 Feb
artefact due			Artefact Assessment Live Webinar 4.30pm			
22 Feb	23 Feb	24 Feb	25 Feb	26 Feb	27 Feb	28 Feb
	Aquatic Respiration Lecture Link Delivered		Aquatic Respiration Live Webinar 4.30pm	Aquatic Respiration Artefact Creation		
1 Mar	2 Mar	3 Mar	4 Mar	5 Mar	6 Mar	7 Mar
artefact due			Artefact Assessment Live Webinar 4.30pm		Optional Module One Exam	

Figure 4 - STEM@University Module 1 Calendar

As also discussed in Section 1.2.4, Transition Year can almost be described as a non-formal year within a student's education. The course is not rigid. It's intention and philosophy changes from school to school, from teacher to teacher. It is an explicit aim of Transition Year to develop student autonomy as they are given freedom to intrinsically explore areas which interest them.

With this understanding, this course wanted to provide an experience for self-selecting students to experience what STEM at a college level STEM might look and feel like. With

this authentic insight, it was hoped that students may be better prepared to choose STEM subjects at Senior Cycle and/or strengthen their college aspirations.

There were 314 students signed up to three different modules of the programme, with each module being priced at €95. 137 students in module 1, 112 students in module 2 and 65 students in module 3. This remote experience had 5 planned elements to it, as can be seen in Figure 3. Within one experience each learner moved through the cycle above three times, with all three lectures from different STEM disciplines. The modules weren't to be repeated and, in this way, students could sign up for different modules if they so wished with no repetition of content.

This course was designed to provide minimal external regulation. Students were able to choose how much time and attention they gave to aspects of the course. There were no external threats or punishments for lack of attendance or non-completion of work. The assignments and exam at the end of the module were completely optional and this was reiterated to the students.

At the planning and design stage of this experience, I provided a selection of literature that would support in selecting the suitable pedagogies to promote student autonomy and online delivery, some of which are discussed in Sections, 2.2.2, 2.3.3, 4.7, and 4.8.

Description	Mode	Student interaction	Time (Hrs)	Aims and Outcomes for each element	Student Task
College Lecture	Recorded Lecture	Autonomous	1	- Advance their understanding on a college level STEM topic - Enhance their note taking skills - Develop their autonomy to select a time and watch lecture	- Watch lecture on their own time - Review notetaking support document and take notes during the lecture - Make a record of anything they didn't fully understand - Submit questions to Teams Chat.
Discussion with TWC Educator	Live Webinar	Synchronous Workshop	1.5	- Scaffold learners with any difficult vocabulary/concepts - Introduce learners to real world applications of lecture content	- Review notes and questions and discuss webinar. - Webinars often included breakout rooms where students were asked to contribute to group work.
Create a Multimedia Artefact	Independent Assignment	Autonomous	≈2	- Develop autonomous learning skills - Further relate lectures and webinar content to situations which would be familiar to students	Students are to complete an assignment and create a digital artefact related to the lecture.
Discussion with TWC Educator	Live Workshop	Synchronous discussion	1.5	- Provide learners with opportunity to assess their own work against the work of others. - Scaffold learners with reflection prompts to begin the critical reflection process.	- Students come together for a session to discuss what they learned and what would they do differently next time. - Students review and comparatively assess the artefacts and reflect on their own artefact. - Webinars often included breakout rooms where students were asked to contribute to group work based on the artefacts created. - Breakout rooms used Assessment for Learning terminology which students would have been familiar with.
Optional Exam	Multiple Choice Question	Autonomous	1.5	- Allow students the chance to check their own learning - Allow students the chance to demonstrate autonomous motivation.	Exam based on content discussed during the Module across all three lectures

Table 1 - STEM@University Programme Overview

Module	Lecture Title	STEM Area	Brief Descriptor
1	Powers of 10	Physics	An exploration of the scale of objects in our universe from the very large to very small.
	Anatomy of a Dynamic Planet	Geology	An introduction to Earth System science. The systems and structures which make up our planet are explained.
	5 in 5	Botany	An explanation of 5 common plant species which people would encounter within their local environments.
2	Buffon's Needle	Maths	A probability problem involving the dropping a needle onto a lined surface. The event occurs when a needle intersects the line, and its probability is directly related to pi.
	Aquatic Respiration	Zoology	The mechanisms through which underwater species extract oxygen from water are explained.
	Medical Devices	Engineering	2 case studies of engineering failure within the medical field are explored: hip replacements and surgical mesh.
3	Disappearance of a Massive Star	Astronomy	An overview of massive stars, spectroscopy, and a missing star in the Kinman Dwarf Galaxy
	The Atmosphere and Climate Control	Geology	Detailing the processes which make our planet habitable and how we are changing some of them.
	Physics of Walking	Physics	A mathematical model is constructed of a person walking to illustrate the effectiveness of modelling on a real-world problem.

Table 2 - Module Titles during STEM@University

4.2 Element 1: Lecture

A module begins with a recorded lecture from a college lecturer. This lecture is typically one which they would deliver to their own 1st year third level students and as a result gives students an experience of what “*college level*” work is. These are recorded directly from courses within the schools of Trinity College Dublin.

The pedagogy within this aspect of the programme is mostly didactic, with students watching the lecture by themselves. They had direct access to the video file and may watch it as many times as they wished. It is utilising the “*flipped classroom*” method of teaching (Bishop & Verleger, 2013). A document specific to each individual lecture was designed to assist students with their note taking and provided to students. This was used as a scaffolding aid for students to assist them with any vocabulary issues that they may have. An example of this note taking document is provided in Appendix 8.5.

4.3 Element 2: Postgraduate Guided Webinar One

The seminar was scheduled to take place 2 days after the lecture was sent to students. This session was facilitated by a postgraduate student (who will be labelled as an educator from hereon) from the relevant school along with TWC’s Programme Co-Ordinator (Teacher). In the seminar, students were guided through the lecture aided by the postgraduate students. Prompts were provided to students to facilitate and aid discussion. The educator was selected largely based on the fact that the lecture topic was somewhat related to their area of study. They provided a session that further contextualised the lecture for the students, often placing their own research alongside it.

The pedagogy within this part of the programme was that of an interactive class. The student group were asked questions by the educator and students were expected to respond either on microphone or in the Microsoft Teams chat function. Specific subject content knowledge was pitched at an age-appropriate level, between Junior Cycle and Senior Cycle level. Students were often asked to enter breakout rooms to complete group work and tasks related to the content on the webinar as an assessment for learning mechanism.

At this webinar, the assignment and reflection were introduced and an example of this was provided in Appendix 8.6. The digital artefact will be detailed further in the next section.

4.4 Element 3: Digital Artefacts

Students were asked to complete an assignment to accompany each lecture of material. They were asked to produce a multimedia artefact which was to be submitted through Microsoft Teams to the programme team. Students submitted three artefacts in total during a module. Artefacts were designed to aid the students in autonomous learning, increasing in levels of autonomy throughout the module; artefact 1 would be well scaffolded, artefact 2 would be somewhat scaffolded and artefact 3 would be the most autonomous of the three. As the students progressed through the three artefacts, the opportunities for personalisation and choice increased. Towards the end of modules, students were given the choice in completing the artefact in whichever media they wished.

Examples of this progression throughout the modules would be:

1. Create your own version of the lecture slides
2. Create a scientific presentation poster
3. Create a PowerPoint presentation with voiceover

Other artefacts included completing scientific reports, Prezi presentations, forensic engineering reports and the creation of adverts and videos.

4.5 Element 4: Postgraduate Webinar Two

After submission deadline the programme co-ordinator picked three artefacts, or specific aspects of artefacts, and shared them during a webinar with students. Students were asked to discuss aspects of these artefacts in breakout rooms. After seeing and discussing the work of other students, students were asked reflection prompts about what they might do differently for their next artefact.

At the end of the lecture, students were then asked to complete a self-reflection evaluation sheet on Microsoft Forms. This reflection was related to their own artefact and was designed to follow a specific reflection cycle; *“What?, So What?, Now What?”* (Borton, 1970, p. 88). An example of this reflection sheet is given in Appendix 8.7. The reflection sheet included a self-assessment rubric which was specific to the artefact which they were asked to create. Reflection as a method of self-assessment is discussed in more detail in Section 4.8.

4.6 Element 5: Optional Exam

The module ended with an optional exam which students could take in their own time over a weekend. The question format was a multiple-choice questionnaire. The content of the exam was based on topics covered in the lectures or in the webinars. This was designed to be fully autonomous, with no threat of deadlines or external forces. After completing the exam, the students instantly received a result. This was designed to serve as a formative learning task where they could further revisit their understanding and perhaps encourage them to read more around the topic.

A total of 119 out of the 314 students completed this exam, 38%. 83 students completed the exam in module 1 (61% of participants), 23 in module 2 (21%) and 13 in module 3 (20%).

4.7 Design Features of STEM@University

After reviewing the available research when it comes to designing the STEM@University course it's clear that there are facets of what has been detailed that were included.

It is desired in a programme such as this for students to be as intrinsically motivated as possible. While it will be impossible to get every single student completing tasks for their own personal enjoyment, the benefits of trying to ensure that they are intrinsically motivated as possible are clearly evidenced. Students should have choice in how they engage with course material, and how they wish to present their work. It should also be personally relevant to them where possible. This can take the form of topic selection when it comes to assessments within chosen teaching modules. Offering choice, flexible learning and assessment options and opportunities for students to develop self-regulation strategies is not only desirable from the perspective those advocating Self-Determination Theory, but also those who are promoting autonomy within online courses also (K.-C. Chen & Jang, 2010).

Some of these features are shown within the pilot programme of STEM@University. Students were given freedom and choice on the topics in which they can do their artefacts on, and this is evident in the artefacts that were submitted. They were able to personalise their own work to make it relevant to their own lives. This was noted within the focus groups as students spoke about the creativity that the course allowed to be used within the artefacts.

“I did other online courses and there wasn’t much independent work, like the artefact. It allowed me, and encouraged me to do further research on the topic, to be more creative about it in my own interpretation.” - Lucy

While the threat of deadlines and punishments are not desirable, they must be balanced with times of feedback (Ryan & Deci, 2000a). As the thought of deadlines, rewards and punishments can dull the innate motivation that educators are wishing to tap into, it’s important that submissions are as soft as possible. STEM@University had a soft submission policy where there were no punishments or consequences if you didn’t submit your artefact or reflection sheet that week. The recorded lectures and loose deadlines gave students the opportunity to learn when it suited them best. The optional exam provided students with an avenue to test their own learning if they wished without any external coercion.

A literature review on the topic of best practise in online STEM courses was performed (B. Chen et al., 2018). The best facets of online courses to impact student learning satisfaction and student perceptions of learning were examined. They found that these were to:

- *Engage students with real-life problems and active experiences.*
- *Provide students with a variety of additional instructional resources, such as simulations, case studies, videos, and demonstrations.*
- *Provide online and face-to-face opportunities for students to collaborate with others, such as peers and teaching assistants.*
- *Faculty should be clear, concise and consistent about instructions, assignments, assessments, due dates, course pages, and office hours, and improve communications with students.*
- *Use Universal Design for Learning principles to design online experiences to benefit all students, not just students with disabilities. (B. Chen et al., 2018)*

It has been observed that online learning environments can provide a safe environment for learners by allowing them space to ask questions without fear of being judged by their peers for doing so (K.-C. Chen & Jang, 2010). This is evident throughout students’ time on the programme. Many students would have been familiar with the chosen virtual learning environment (Microsoft Teams) as their schools would have been using it or similar software

during the COVID-19 enforced school closures. Students were comfortable in asking questions related to the course content or even technical issues and often students were also comfortable in answering those questions before a member of TWC staff was able to answer them. It was evident that this was a safe learning environment.

4.8 Reflection as Feedback

Reflection is used as a metacognitive tool which Cottrell (2005) describes as being deliberate, structured, focused and has the end goal of developing understanding. Its use has been a focus of recent educational reforms within Ireland (NCCA, 2015). The NCCA describe that they wish for students to become *“reflective active participants in their learning and for teachers to support this.”* (NCCA, 2013)

Structured reflection helps people to deepen understanding and change future actions based on changing perspective, analysing one’s own role, referring to conventional or academic wisdom (Cottrell, 2005). The benefits of reflection on the practitioner include self-management, emotional maturity and using experience to benefit the person who is doing the reflection and others, while also aiding more effective study and learning (Cottrell, 2017). The benefits of reflection can also lead into the skill of critical thinking. This is a skill that is often desired by those designing curricula in both formal and informal settings (Kelly & Erduran, 2019). The importance of training facilitators in enabling reflections in non-formal education settings has been emphasised given its role in self-assessment and fulfilling the desired goals of the experience (Roche et al., 2019).

A self-assessment sheet was used to enable student reflection to further autonomous learning within the realm of language education. Students were able to assess their own failings and areas of improvement to create personalised goals for future activities (Warchulski, 2015).

The benefits of using reflection as a tool of assessment for all learners in physics education has been detailed by White and Frederiksen (1998). They found that giving students guidelines for judging their own work helped to students to have more confidence in understanding what was required of them. Within this study a *“reflect and try again”* cycle is

repeated, while students are driven to towards trying harder under the idea that their research will be assessed by themselves, their peers, and teachers. Continuing cycles of reflection and exploration were also used to deepen conceptual understanding in the high-school physics classroom (Wade-Jaimes et al., 2018).

This continuing cycle of reflection and development is a feature of the programme that is evident as students must go through three cycles of reflection in each module as seen in Table 1. An example reflection sheet is included in Section 8.6. While the cycle of reflection is not built upon conceptual understanding, developing content knowledge is not the explicit intention of this course. Within STEM@University the desired outcome is the development of the student's STEM identity and as a result the reflection cycles were designed to enable this.

4.9 Conclusion

In this chapter, the intervention has been detailed. Initially the specifics were outlined and formats of the intervention. This programme was designed to introduce STEM learners to the college environment and from examination of the specific elements involved, it was seen that students were given the opportunity to get an idea of what college STEM looks like.

The programme also took steps to address issues which arise in courses which aim to increase student autonomy, as large amounts of freedom and choice were given to students.

While the programme used student reflection and self-assessment to enact long term change, perhaps an explicit explanation of the importance of reflection could have been provided to students for them to get the maximum amount out of this specific experience.

5 Findings

As discussed within the Theoretical Framework, this research study aims to evaluate the student experience during their time on the STEM@University programme. While the desired outcome of the programme is to develop the student's STEM Identity, this will be assessed by measuring the students' STEM capital, self-efficacy, and autonomy as well as other materials presented by the students into building an argument for how these combine to enhance an individual's STEM identity.

In Chapter 3 the quantitative instruments were introduced, and the qualitative data collection methods was shown and reasoned. This chapter will share and discuss the findings from these instruments and begin by presenting the data from each quantitative instrument individually.

Research Question 2(d) relates to the student STEM Identity development during their time at STEM@University. To assess this, 12 case studies in Section 5.4 have been compiled where the individuals experience is detailed as explicitly as possible. Within the case studies, it is noted what students were hoping to achieve by participating in STEM@University, their own reflections on work they submitted along with their STEM capital, sources of science self-efficacy and autonomy development.

5.1 STEM Capital

5.1.1 Quantitative Results

Each of the 14 items on the index of science capital instrument has a corresponding weighting as to how important they are to the centrality of the notion of science capital. The scores are then summed to create a single score for science capital for each student. The final step of the index of science capital as described involves the transformation of the population data into a scale from 0-100 and division of the dataset into those scoring 0-33.3, 33.4 to 66.6, 66.7 to 100 consisting of those with low, medium and high science capital respectively (Moote et al., 2019). To compare the STEM Capital of the students completing STEM@University to the large sample used previously, the 0 and 100 score were set at the minimum and maximum values possible to be found using the index of science capital (Archer et al., 2015; Moote et al., 2019).

In the radar chart below, the change in STEM capital of 12 individuals during their time at STEM@University can be observed. The scores are normalised within the group to exacerbate and highlight any shifts that occurred during their time at STEM@University.

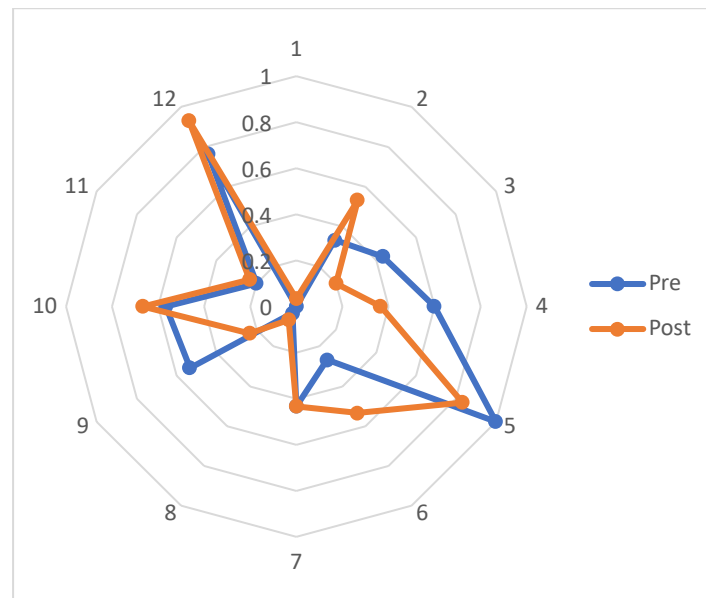


Figure 5 - Radar Plot of normalised STEM Capital data for pre and post STEM@University

As observed in figure 5, 7 students (Teresa, Karen, Eoin, Amy, Erica, Josephine and Caoimhe) demonstrated an increase in STEM capital, 4 decreased (Daithi, Bríd, Eibhlín and Aoife) and 1 remained constant (Shauna).

A decrease in the overall group mean is observed among these 12 individual cases and this is detailed in Table 3.

N	Mean Pre $\pm$ Standard Deviation	Mean Post $\pm$ Standard Deviation	Δ
12	55.36 $\pm$ 8.63	55.11 $\pm$ 8.57	-0.25

Table 3 - Changes in Mean in STEM Capital between Groups.

As far as the author is aware, this one of the first studies outside of the ASPIRES group to use the STEM capital instrument (Moote et al., 2019, 2020). Comparisons between this STEM capital data to the data presented previously are made below.(Archer et al., 2015; Moote et al., 2019). In Table 4, the STEM capital of every student who completed a pre-questionnaire is presented. As expected, there are noted differences between the STEM Capital possessed by the general student population and those who chose to partake in STEM@University.

	Age	High STEM Capital (%)	Medium STEM Capital (%)	Low STEM Capital (%)
Moote 2019	17-18	4.9	62.4	32.6
Archer 2015	11-15	5.1	67.6	27.2
STEM@University	15-16	6.89	89.66	3.44

Table 4 - STEM Capital of Populations

After examination of the 12 student experiences, the students who completed both the pre and post questionnaires, there was a sample population who consisted mainly of those in the medium STEM capital group with 1 student falling into the group with high amounts of STEM capital. It should be noted that 1 student, Caoimhe moved from having medium amounts of STEM Capital to having high amounts of STEM capital and this is shown in Table 5.

When evaluating the effectiveness of the programme, it is encouraging to see more positive changes than negative. When looking at the entirety of the unmatched data set ($N_{Pre}=29$, $N_{Post}=16$) increases are seen in means from 52.17 to 52.97 in module 2, and another increase from 55.06 to 56.06 in module 3.

Student	Gender	Pre STEM Capital	Post STEM Capital
Teresa	F	Medium	Medium
Karen	F	Medium	Medium
Daithi	M	Medium	Medium
Bríd	F	Medium	Medium
Eibhlín	F	High	High
Eoin	M	Medium	Medium
Shauna	F	Medium	Medium
Amy	F	Medium	Medium
Aoife	F	Medium	Medium
Erica	F	Medium	Medium
Josephine	F	Medium	Medium
Caoimhe	F	Medium	High

Table 5 - STEM Capital Groups for 12 Students

Upon further deeper investigation into the prompts contained within the STEM capital questionnaire, there are some questions that are more relevant and useful to explicitly examine the students' STEM capital in the context of STEM@University. Specifically, these prompts are:

- *A science qualification can help you get many different types of job.*
- *I know how to use scientific evidence to make an argument.*
- *It is useful to know about science in my daily life.*
- *When you are NOT in school, how often do you talk about science with other people?*
- *When not in school, how often do you read books or magazines about science?*
- *Who do you talk to about science?*

Question	Improve/Disimprove				
	+2	+1	0	-1	-2
A science qualification can help you get many different types of job	-	3	9	-	-
I know how to use scientific evidence to make an argument.	-	3	7	2	-
It is useful to know about science in my daily life.	-	2	5	5	-
When you are NOT in school, how often do you talk about science with other people?	1	3	4	3	1
When not in school, how often do you read books or magazines about science?	-	3	3	4	2

Table 6 - Changes in STEM Capital Questions

Within the final question of the instrument, “*Who do you talk to about science? (Select as many as relevant)*” it is noted that

- 4 students started to talk their friends about science compared to 1 who reported no longer spoke to their friends about science.
- 2 students started to talk their teachers about science compared to 1 who reported no longer spoke to their teachers about science.
- 1 student started to talk their extended family members about science compared to 1 who reported no longer spoke to their them about science.
- 2 students no longer spoke to their siblings about science.
- 1 student no longer spoke to their parents or carers about science.

5.1.2 Discussion

In this section, it is aimed to contextualise and elaborate upon some of the notable results within Section 5.1.1. Archer's comment in relation to informal science learning environments seems pertinent here.

"..there is no simple, linear process whereby a particular ISL practice will produce the same outcome in all participating youth, as this will be mediated by interactions between each unique habitus, capital, and field in a particular time and space (such as from their previous experiences). However, there may be broad, discernible patterns in terms of shared, collective aspects of habitus and capital in relation to institutionalized features of a field." (Archer et al., 2021).

While this quote relates to the informal learning space, Archer speaks of the complexities of interactions between the habitus and the field. Any decreases in measured STEM capital among students should be unexpected and it would have been hypothesised that students attending a STEM course should report higher scores in this instrument if any change were to occur. It could be asked whether students overestimated their ability to make a scientific argument or overestimated how relevant science was to their daily lives when they signed up to the course? Is it possible that seeing the work of students with high STEM capital caused them to re-evaluate their own? While completing STEM@University, the programme is showing some students who may have been extremely comfortable in their own STEM habitus to new people and new concepts. These interactions with others and with newer material could force students to evaluate their response to questions like *"I know how to use scientific evidence to make an argument"* and *"It is useful to know about science in my daily*

life". From the focus group that was conducted there are some indications of this, where students responded that "*..It was about things that you wouldn't really be taught in a science class.*" – Niamh and "*I really enjoyed it. It was a very diverse experience*" – Lucy.

One thing that should be considered is time frame of data collection. Decreases in responses to questions relating to speaking to people about science might be related to the fact that data collection took place in April to June of 2021, after a prolonged period of isolation due to the COVID-19 pandemic. It must be noted that a student changed her answer from "*Once a Week*" to "*Once a Year*" which would be larger than the period between the data collection points before and after the module. Another aspect to consider is the hypothetical question as to whether it was possible for this programme to build quantifiable STEM capital in such a short period of time? Indications from previous studies would suggest that it is possible. (Archer et al., 2021).

The intake of the course, where the student population is more likely with someone with higher amounts of STEM capital and less likely to be someone with lower STEM capital compared to the general population should be noted. This study's mean of a STEM capital score of 55.36 with a standard deviation of 8.63 implies a very different student population to that studied in previous studies. A previous study of 11–15-year-olds reported means of 41.57 with a standard deviation of 14.71 while an older population sample of 17–18-year-olds contained a mean of 41.00 and a standard deviation of 15.53 (Moote et al., 2019). Other studies have indicated that students not only have academic expectations of similar programs, but social expectations too as they look for like-minded peers and teachers who are experts in their field (Tolppanen & Tirri, 2014). While the programme intended to increase the STEM capital of students, the by-product of exposing students with high amounts of STEM capital to the possibility of STEM courses and STEM careers can only be a good thing. From the focus group data, students not only experienced this from other students, but from the "*teachers*" taking the modules as they saw them as experts.

5.1.3 Qualitative Results

While some quotes from the focus group have already been mentioned in Section 5.1.2 where the results from the index of science capital instrument were discussed, the focus group itself was evaluated for evidence of STEM capital growth amongst those taking the course.

5.1.3.1 Existing Capital

It was desired to see whether students would feel that their lives in STEM had changed because of attending the course but firstly it should be considered how much capital the participants of the focus group report having at the commencement of the programme. While it will be difficult to classify whether each student has high, medium, or low STEM capital, the focus group data can be used to assess what the student's feelings in relation to STEM were at the beginning of the programme and what changed with respect to this they report during the programme and what facets of the course facilitated that change. Of the 4 students that attended the focus group, 2 (Daniela and Lucy) were already very firmly set on their ambitions to continue in STEM before attending the course and 2 (Edward and Niamh) were unsure as to whether they wanted to pursue STEM.

"I already was interested in STEM but it definitely solidified the fact that I want to go into further research after undergrad. Seeing Masters and PhD students who were teaching, really solidified that is that I want to do after my degree, to do a PhD." – Daniela.

"I was also really confused whether I wanted to go into STEM or wanted to go into Arts 'cause I've always liked English but I also really like science as well. I thought that doing the course would give me a taste of what it would be like in college, because you don't really get to do much science in Junior Cert." – Niamh.

5.1.3.2 Immediate Changes for Students

In the focus group, changes in STEM capital were intended to be measured by asking students about any changes they think will occur in their immediate and long-term future. All 4 students reported intentions to pick physics for the Leaving Certificate exam, with 2 (Niamh and Edward) out of the 4 students reporting that participating in STEM@University changed their mind about studying physics.

"...But I think if I could go back and do my subjects out, I'd think about doing physics more." – Edward.

Whereas two were already comfortable with their decision to study physics.

“...I didn’t really want to pick physics cause I didn’t know much about it and the only knowledge I had was that it was like math, just doing math more times a week wasn’t that enticing to me. But this course showed me that it can be really exciting and it applies to practical aspects. It’s taking math but it also how maths works by walking or running or competition. It really made me think more about it and choose it for the Leaving Cert as I got a bit more excited about it from doing the course.” – Niamh.

It should be asked what aspects of the course changed the minds of Niamh and Edward. It’s been found that students who pick physics to study post-16 in school are more likely to have large amounts of cultural capital (DeWitt et al., 2018) and previous studies on science/STEM capital have correlated it strongly with the presence of cultural capital. (Archer et al., 2015)

It is in the author’s view safe to assume that these students’ STEM capital did increase.

Also, to note was a response in relation to independently looking up things that they found interesting from Daniela. This could be seen as an indication of her STEM capital increasing.

5.1.3.3 Long-Term Changes for Students

While the author is aware of the caveats of this data, it is interesting to note that all 4 participants reported that they would be more likely to pursue taking a STEM related course for their undergraduate studies. 1 out of the 4 students (Niamh) reported being open to studying STEM subjects when she wasn’t so open to this before the programme.

“For me it would be picking my degree because before the course I was like I’m definitely doing economics or politics or something but doing the course has definitely widened my horizons. Now I feel that I can maybe do a STEM course in college” - Niamh

These results would indicate that the students all have high amounts of STEM capital with Niamh’s increasing.

5.1.3.4 Reasons for increased STEM Capital

When the findings of the focus group are examined, it was reported that the social experiences of seeing Postgraduate students take classes in their field reduced the intimidation of studying STEM and provided role models for the participants. The intimidation aspect of STEM will be discussed in more detail in the self-efficacy data.

“Being taught by masters students who know what they want, you’re getting good quality teachers...It does make you more comfortable and it does break you into the world of STEM which can be quite intimidating sometimes” – Edward.

“You never really see people doing Masters or PhDs. It’s not something that teachers will tell you when they are asking what you want to do, “Do you want to go into research in the subject?”. And then see in the Disappearance of a Massive Star, they were studying and showed the interesting things that you can do for a PhD” – Daniela.

Other aspects which arose within the focus group include the theme of the vastness of STEM and how each subject can interact and depend on others. For the students within the focus group, 3 out of the 4 (Niamh, Lucy and Edward) reported that this was something that they reported as being an important development for them during the programme.

“ I just think it’s really good to do a course like this because in secondary school the subjects are so segmented and they never really interact with each other.”- Niamh.

“...The one that Niamh said, you know learning about the deeper aspects of STEM. Realising that physics isn’t just one thing, it’s like deeper. For me, it was that STEM isn’t just about maths and engineering. It’s not just that. When they say science, technology, they do mean all the sciences, like biology, chemistry and physics. I didn’t realise that before. I would put a high value on that as it expanded my general knowledge of STEM.” – Lucy.

The course also made two of the students (Lucy and Niamh) aware of aspects in physics that they had not seen previously during their Junior Cycle studies.

“And also the variety in physics, I learned about. I wasn’t that interested in physics at the beginning, I thought it was just Math. I just thought it was what I was learning in Math mixed in with what I was doing in science. But because all the sections of the module were really different, it was just really fun to see what they would be like” – Niamh

Other differing aspects that the course aimed to bring out, such as creativity, specific scientific skills or interactions with working scientists who are giving talks.

“Some of the skills that I put down are like, doing up the artefacts. Two of my artefacts were that you had to present research or create your own thing. So that skill of report writing, I had never done a scientific report before properly before we were given the artefact about Buffon’s needle and the different ways of finding pi” – Lucy

Originally, the index of science capital quantitative instrument was chosen as it was desired to see if students’ intentions to persist and move within STEM might have changed within their time at STEM@University. Some change was evident within the students in this regard.

“For someone who was unsure about STEM, and they did this course and is now coming out the other side of it that they would be a lot more mature and a lot more serious, and a lot more grounded again in that this is what they wanted to do. And would have given them the push.” – Edward.

“Then creativity as well, I found that the artefacts that they asked you do weren’t that specific. So you really got to take your own interpretation and everyone’s project kinda looked different” – Niamh.

“Like I was seeing Masters and PhD students saying that they were studying this in university, so, even just from seeing them doing something that I would be genuinely interested in. And then realising that that was STEM was really helpful for me” – Niamh.

5.1.4 Summary of STEM Capital findings

Upon assessing student’s STEM capital, one must be cognisant of varying factors when students are reporting this data during the focus group. From self-selection in participation within the focus group to the differences in saying you’ll change subjects to changing subjects, analysis of measuring *“intentions to persist”* should be evident in the transcript beyond the obvious statements. Students reported seeing STEM in a different light after completing the course, this is in the opinion of the author evidence of growth in STEM capital. They engaged with scientists and other students and thought that maybe people like them could actively participate and work in STEM. Students on the focus group reported seeing the Masters and PhD students working on the modules as actual real scientists who were willing to communicate and help them, removing psychological barriers that may have existed within their minds.

5.2 Sources of Science Self-Efficacy

Each of the 4 subscales on the Sources of Science Self-Efficacy are presented below. Scoring the instrument sees students' responses to all statements were assessed using a Likert-type scale ranging from 1 (Definitely False) to 6 (Definitely True). In its raw form, the instrument is an average score of the 6 items which contribute to each subscale.

In the radar plots, shown in Figure 6, the change in sources of science self-efficacy of 12 individuals during their time at STEM@University can be observed. The scores are normalised within the group to allow us to compare the changes that occurred within each student during their time at STEM@University. To be noted when comparing this study's work to some others (J. A. Chen & Usher, 2013) the physiological state subscale was reverse coded by the author. A high score within this study means that students are comfortable within science compared to the Chen and Usher study which would report that a high score indicates high amounts of stress, nervousness, and a negative response to science. The mean of the group is presented below. Chen and Usher (2013) used the sources of science self-efficacy scale to group students together in groups. These were students who source high amounts of science self-efficacy from multiple sources, students who source their self-efficacy highly from mastery, students who have a moderate profile with no distinguishing patterns and students who would be deemed at risk as they have little successes in science. As reported by Chen and Usher (2013) with regards to the multi-source group this was said;

"The Multi- Source group was named as such because students in this group seemed to be attentive to multiple sources of self-efficacy rather than just one or two. These students were characterized by strong mastery experiences ($M = 5.38$), vicarious experiences ($M = 4.57$), and social persuasions ($M = 4.96$), along with low physiological and affective arousal ($M = 1.58$)." (Chen and Usher 2013)

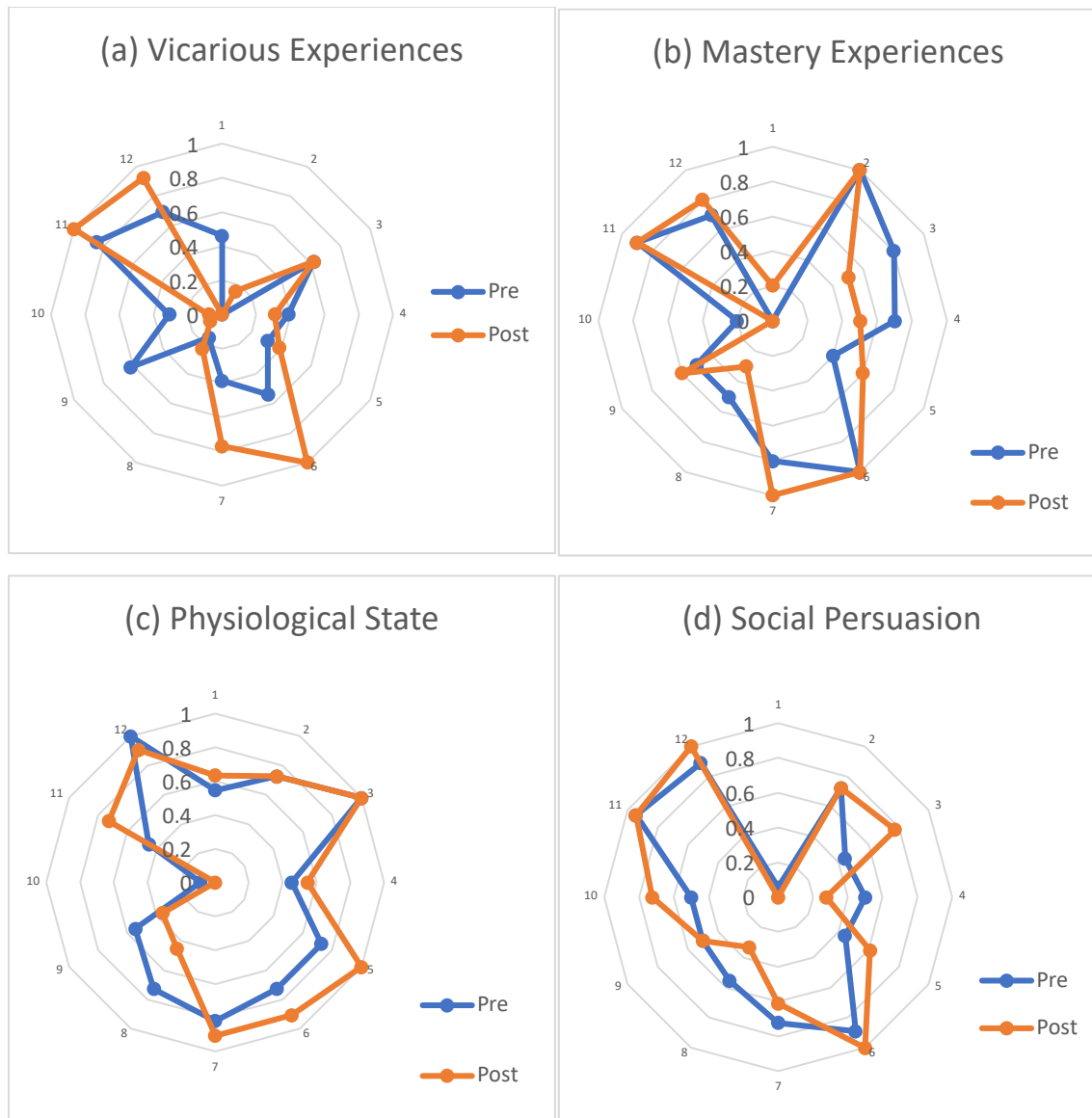


Figure 6 - Radar plots of pre and post (a) Mastery Experiences changes, (b) Vicarious Experiences (c) Physiological State (d) Social Persuasion changes

N=12	Mean Pre $\pm$ Standard Deviation	Mean Post $\pm$ Standard Deviation	Δ
Mastery Experiences	5.25 $\pm$ 0.48	5.23 $\pm$ 0.54	-0.02
Vicarious Experiences	4.79 $\pm$ 0.48	4.83 $\pm$ 0.83	0.04
Social Persuasion	4.79 $\pm$ 0.48	4.87 $\pm$ 0.92	0.08
Physiological State	4.31 $\pm$ 0.48	4.42 $\pm$ 0.56	0.11

Table 7 - Changes in Mean in Sources of Science Self-Efficacy between groups

5.2.1 Discussion of Means

Upon inspection of the mean scores of the 12 case studies, it should be noted that the students participating in this study are very much comparable to the Multi-Source Group which is presented in previous work (J. A. Chen & Usher, 2013).

While shifts in self-efficacy sourced from mastery experiences would be desirable as it is the most powerful form of self-efficacy (Bandura, 1997) providing meaningful shifts in mastery experiences might prove difficult in a 6 week programme. Could students' own perceptions about their abilities in doing science tasks have changed positively during this time frame, especially as they were already at such a high level? Exposing students to many new avenues of science which they previously may not have heard of should make students uncertain about their own scientific competencies as they know that they have not mastered them yet.

Slight increases in vicarious experiences mainly relate to interactions with other students. It could be fair to hypothesise that when students came from their individual schools to participate at STEM@University, they may have been the person with the most science self-efficacy in their class. Did seeing other, like-minded students with high amounts of self-efficacy increase their own confidence in themselves and therefore their self-efficacy?

Positive shifts in 4 out of the 6 subscales that made up the social persuasion subscale are interesting, especially as could be all seen as being questions that are outside of the direct sphere of influence of STEM@University. In the STEM capital instrument, it was noted that students reported talking to more their friends more about science, so is it possible that the programme provided an avenue for conversations related to the participants' own progress in science with their classmates and friends? Were the interactions with their parents of a higher value even though there wasn't an increase in the number of them taking place?

Students had a physiological and affective score that indicated that they were incredibly comfortable within science before they began STEM@University. This increased, but not significantly so. This does match what students reported within the focus groups and this will be expanded upon in Section 5.2.6.

5.2.2 Mastery Experiences

Within this section, the results from self-efficacy sourced from mastery experiences will be presented, contextualised, and discussed. As discussed in Section 2.2.1, mastery experiences are a very powerful source of self-efficacy for students.

	+4	+3	+2	+1	0	-1	-2	-3	-4
I make excellent grades on science tests	-	-	-	1	7	4	-	-	-
I have always been successful with science	-	-	-	3	7	1	1	-	-
Even when I study very hard, I do poorly in science	-	-	-	2	7	3	-	-	-
I got good grades in science on my last report card	-	-	-	4	8	-	-	-	-
I do well on science assignments	-	-	-	1	7	4	-	-	-
I do well on even the most difficult science assignments	-	-	-	2	8	2	-	-	-

Table 8 - Changes in Mastery Experiences

Upon analysis of the 6 items that contributed to this scale, noticeable shifts were seen in relation to 3 of the 6. “*I make excellent grades on science tests*” and “*I do well on science assignments*” saw 4 students decrease their score by 1 compared to 1 who increased it by 1. “*I got good grades in science on my last report card*” saw 4 students increase their score by 1 point.

When looking at what questions could be influenced by STEM@University, it is hypothesised that “*Even when I study very hard, I do poorly in science*”, “*I do well on science assignments*” and “*I do well on even the most difficult science assignments*” are worthy of deeper examination. A slight difference was seen within the reverse coded “*Even when I study very hard, I do poorly in science*”. “*I do well on science assignments*” saw a noticeable decrease as remarked upon earlier and “*I do well on even the most difficult science assignments*” saw no net change.

Due to the overall experience of reflecting upon your own work within this programme, it might be hypothesised that students saw a new level of learning of presentation and of effort from other students within this course. What was “doing well” before was suddenly something which could be improved upon, and this could be new for students within such a group.

When looking at the entirety of the unmatched data set ($N_{\text{Pre}}=29$, $N_{\text{Post}} = 16$) the pre was measured at 5.25 and the post was measured at 5.28. Collating this work with the focus group, students were seen to report statements that would indicate that do indeed have high amounts of self-efficacy within science sourced from mastery experiences.

“I always knew that I wanted to do STEM, this has really solidified the fact. It’s something that I really I want to do, it’s something that I find interesting. I’m doing all sciences for the Leaving Cert... I definitely will look up more stuff in physics over the summer, more stuff that I find interesting myself.” – Daniela.

5.2.3 Vicarious Experiences

Within this section, the results from self-efficacy sourced from vicarious experiences will be presented, contextualised, and discussed. Self-efficacy sourced from vicarious experiences has previously been discussed in Section 2.2.1. Given the nature of STEM@University, it would be hypothesised that this source of self-efficacy would increase during this programme.

	+4	+3	+2	+1	0	-1	-2	-3	-4
Seeing adults do well in science pushes me to do better	-	-	2	4	1	4	1	-	-
When I see how my science teacher solves a problem, I can picture myself solving the problem in the same way	-	1	1	4	2	-	4	-	-
Seeing kids do better than me in science pushes me to do better	1	-	-	5	3	-	3	-	-

When I see how another student solves a science problem, I can see myself solving the problem in the same way	-	-	3	4	0	4	1	-	-
I imagine myself working through challenging science problems successfully	-	-	1	2	4	3	1	1	-
I compete with myself in science	1	-	-	2	4	5	-	-	-

Table 9 - Changes in Vicarious Experiences

Here noticeable changes were seen in 3 out of the 6 items which contributed to this scale.

An increase was seen in the scores of *“Seeing kids do better than me in science pushes me to do better”*, *“When I see how another student solves a science problem, I can see myself solving the problem in the same way”*. A decrease was noted in *“I imagine myself working through challenging science problems successfully”*.

It’s hypothesised that all the questions here could be influenced by participation in STEM@University given the vicarious nature of the programme. While students learned new materials during their lectures, they assessed their own work largely by comparing to the work of their peers. They were introduced to scientists who were experts in their field, and they were showing them what science was like.

When looking at the entirety of the unmatched data set ($N_{Pre}=29$, $N_{Post} = 16$) a subtle increase in means from 4.65 to 4.83 was noted.

5.2.4 Social Persuasion

Within this section, the results from self-efficacy sourced from social persuasion will be presented, contextualised, and discussed. Self-efficacy sourced from social persuasion has previously been discussed in Section 2.2.1.

	+4	+3	+2	+1	0	-1	-2	-3	-4
My science teachers have told that I am good at learning science	-	-	-	-	11	1	-	-	-

People have told me that I have a talent for science	-	-	-	3	5	4	-	-	-
Adults in my family have told me what a good science student I am	-	-	-	6	3	2	-	1	-
I have been praised for my ability in science	-	-	2	3	4	3	-	-	-
Other students have told me that I'm good at learning science	-	-	2	2	6	1	1	-	-
My classmates like to work with me in science because they think I'm good at it	-	-	2	4	5	-	1	-	-

Table 10 - Changes in Social Persuasion

It's hypothesised that 5 out of the 6 questions could be influenced by participation in STEM@University,

- People have told me that I have a talent for science.
- Adults in my family have told me what a good science student I am.
- I have been praised for my ability in science.
- Other students have told me that I'm good at learning science.
- My classmates like to work with me in science because they think I'm good at it.

Noticeable changes in 4 out of the 6 items which contributed to this scale were seen.

An increase was noted in *"Adults in my family have told me what a good science student I am"*, *"I have been praised for my ability in science"*. Another noticeable increase was seen in *"Other students have told me that I'm good at learning science"*. Changes were noted in *"My classmates like to work with me in science because they think I'm good at it"*.

It is possible that the course provided opportunities for discussion for students with significant others in their lives. Indeed, given that 10 of the 12 matches samples belonged to girls, this echoes with earlier work (Britner & Pajares, 2006) conducted on the Sources of Science Self-Efficacy amongst girls when they said that,

“...the academic self-efficacy beliefs of girls may be more strongly informed by the messages they receive from teachers and from adult family members and significant others than from their actual academic accomplishments.” (Britner & Pajares, 2006).

5.2.5 Physiological State

Within this section, the results from self-efficacy sourced from a student’s physiological state will be presented, contextualised, and discussed. Self-efficacy sourced from physiological state has previously been discussed in Section 2.2.1. It would be hoped by the programme that participation within it would have students feeling more comfortable and confident as they do STEM.

	+4	+3	+2	+1	0	-1	-2	-3	-4
Just being in science class makes feel stressed and nervous	1	-	-	-	6	5	-	-	-
Doing science work takes all of my energy	-	-	1	3	5	3	-	-	-
I start to feel stressed-out as soon as I begin my science work	-	-	-	2	6	3	-	1	-
My mind goes blank and I am unable to think clearly when doing science work	-	-	-	1	9	2	-	-	-
I get depressed when I think about learning science	-	-	-	1	9	2	-	-	-
My whole body becomes tense when I have to do science	-	-	-	1	9	2	-	-	-

Table 11 - Changes in Physiological State

Overall, a shift was seen in the direction of higher self-efficacy being sourced from Physiological State across 5 of the 6 items on this scale, but 1 item stood out.

5 people decreased their score by 1 to *“Just being in science class makes feel stressed and nervous”* in comparison to 1 person who increased their score by 4. The student who reported

increasing amounts of stress and nervousness after participating in the course was Amy. Her Physiological State score remained high after completing the course scoring 5 out of a maximum of 6. Amy's response is discussed in more detail in Section 5.4.9.

It's hypothesised that all the items in this section would be possibly influenced by participation in STEM@University.

When looking at the entirety of the unmatched data set ($N_{Pre}=29$, $N_{Post} = 16$) students self-efficacy sourced from physiological states increased from 5.09 to 5.46.

5.2.6 Summary of Qualitative Self-Efficacy Findings

5.2.6.1 Pre-existing Self-Efficacy

Given what is known about self-efficacy being a predictor of academic achievement and intentions to persist within STEM it was seen that this was something to assess within the focus groups.

Before the course, it was evident that Lucy and Daniela had large amounts of Science Self-Efficacy that would best be classified as being sourced containing high amounts of Mastery.

"... I was going to do it for the first module, but I was already going to be doing an engineering course in DCU and I thought it might be a bit too much focus in that area. I was like, I should be exploring other fields, but then I signed up for the second module, and really enjoyed it. " – Lucy.

Niamh and Edward both signed up as they have had siblings attend college in Trinity and wanted to see what the college experience would be like, this would be best classified as being sourced containing high amounts of vicarious experiences.

"I also did the course as both my brother and sister both went to Trinity and I wanted to see what it was like. I was also really confused whether I wanted to go into STEM or wanted to go into arts cause I've always liked English but I also really like science as well. I thought that doing the course would give me a taste of what it would be like in college" – Niamh.

This result would match the findings from the quantitative study which would place the students within the Multi-Source group (Chen & Usher, 2013).

5.2.6.2 Development of Self-Efficacy in STEM@University

The prompt which was designed to elicit response from students about their self-efficacy development during STEM@University was whether the course made them more or less comfortable within STEM. All the students reported that their experience at STEM@University made them more comfortable; even those who possibly would be categorised as having little amounts of anxiety and stress related to STEM.

"It definitely made me more comfortable as I knew already about the different aspects of STEM, like I talked about earlier. The scariest thing about STEM was that I didn't know much about STEM. I only had the surface knowledge of engineering, physics and biology, I didn't have any idea as to what was really different about them, or why I would do one over the other." – Niamh.

"I think it definitely did make me more comfortable because it helped me realise that there are so many different aspects in the huge field of STEM so that you can go into."
– Lucy

"Definitely more comfortable, but I've kinda always really had an interest in Science. I knew that I liked it and everything. I kinda just liked learning new things within each individual module." – Daniela.

"It definitely did...It sorta goes into different avenues that you can really expect from someone doing like a masters in something like that." – Edward.

During the focus group, one of the main themes identified by the students and explored by the facilitator was the intimidation that students feel when they encounter or think of STEM. This is particularly interesting to hear from students who have high amounts of both STEM capital and science self-efficacy.

"It does make you more comfortable and it does break you into the world of STEM which can be quite intimidating sometimes." - Edward

"It's sort of seen that you have to be of a certain IQ level to be into STEM, that you're really smart or you're really mathsy or something" – Edward

“I definitely agree with Daniela and Edward a lot in terms that I’ve seen the intimidation that some of my classmates that haven’t had an experience of this course who wouldn’t go towards STEM at all” – Lucy.

When asked about this intimidation, Niamh, who previously had questions about whether she should pursue STEM or a course in arts responded;

“I definitely agree (with what they said), getting a wider knowledge of STEM and it being intimidating...I just think it’s really good to do a course like this because in secondary school the subjects are so segmented and they never really interact with each other. So that have subjects interact that takes away the whole intimidation aspect to STEM cause it links into so many different aspects.” – Niamh.

“A lot of students just think of science as something boring and they just completely steer themselves away from it, towards the arts or business, whereas I feel that if the science course in our schools was taught the same way that it was taught in the STEM programme that we did here, I feel like a lot of students would realise that science has a lot more creativity in it, that it’s not just memorisation. I think there is an intimidation that needs to go away and I feel that it could be done if science was taught not like in a way in the (national) programme.” – Lucy.

Returning to the original research question given the data presented by the students about their time during the programme, can it be ascertained whether students had higher self-efficacy at the end of the course? While it has been previously alluded to the sampling bias that may exist by the students who self-selected themselves to participate within this study, it has been found that the features which were designed to heighten self-efficacy were apparent to the students themselves.

Whether that was the content itself,

“I feel more grounded, and knowledgeable about Earth itself. The operations that are going on around us that we don’t really take in on a day to day process. At the same time from that, you develop a lot more critical thinking skills, that if one star dies another star will form out of that. So you need to know that the step by step process until it becomes engrained into your brain.” – Edward.

The skills developed,

“That skill of report writing, I had never done a scientific report before properly before we were given the artefact about Buffon’s needle and the different ways of finding pi. So that for me was a skill that I found I learned, writing up a scientific report, because that I will use that in the future.” – Lucy.

Encountering scientists presenting their course,

“You never really see people doing Masters or PhDs. It’s not something that teachers will tell you when they are asking what you want to do, “Do you want to go into research in the subject?”. And then see in the Disappearance of a Massive Star, they were studying and showed the interesting things that you can do for a PhD” – Daniela

Or seeing many different disciplines or other students’ work within STEM.

“So that have subjects interact that takes away the whole intimidation aspect to STEM cause it links into so many different aspects.” – Niamh.

“Then creativity as well, I found that the artefacts that they asked you do weren’t that specific. So you really got to take your own interpretation and everyone’s project kinda looked different.” – Niamh.

5.3 Autonomy

5.3.1 Self- Regulation Questionnaire - Academic

Changes in each of the 4 subscales on the self-regulated questionnaire – academic are presented below. Scoring the instrument sees students’ responses to all statements were assessed using a 4-item Likert-type scale where the options available for selection were “Very true”, “Sort of true”, “Not very true” and “Not at all True”. Within the SRQ-A, questions are attributed to assessing the 4 subsets within motivation according to Self-Determination Theory; extrinsic motivation, introjected regulation, identified regulation, and intrinsic motivation. There are 9 questions to assess Extrinsic and Introjected Regulation and 7 questions to assess Intrinsic Motivation and Identified Regulation. The 4 subscales for extrinsic motivation, introjected regulation, identified regulation, and intrinsic motivation are calculated by averaging of the scores of the items which contribute to their subscale.

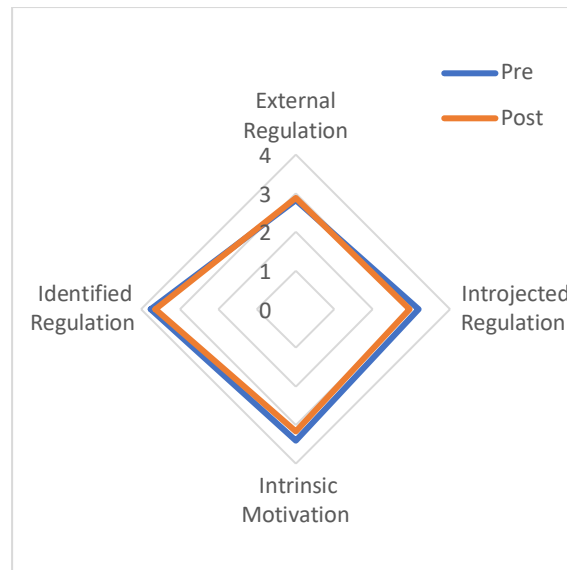


Figure 7 - Changes in Subscales on SRQ-A

Consequently, the relative autonomy index (RAI) is calculated by the following formula:

$$RAI = 2(Intrinsic) + Identified - Introjected - 2(External).$$

In the radar chart in Figure 8, the change in RAI of 12 individuals during their time at STEM@University can be observed. The scores are normalised within the group to exacerbate and highlight the changes that occurred to each student during their time at STEM@University.

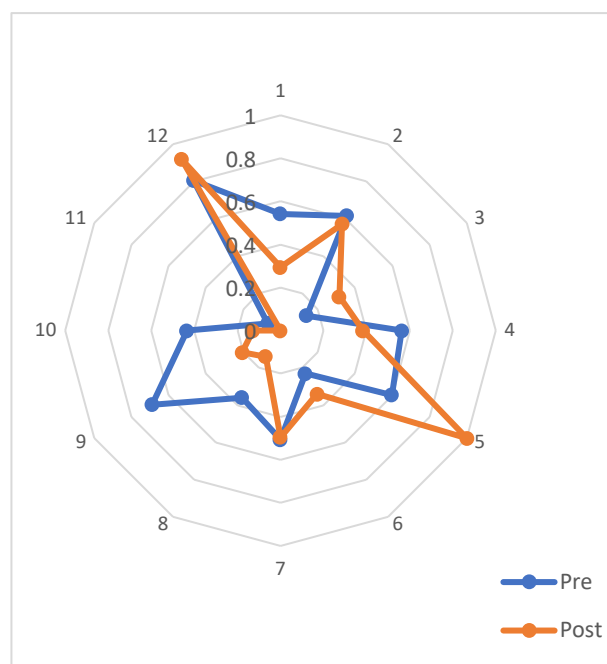


Figure 8 - Changes in Relative Autonomy Index

4 students increased their RAI and 8 decreased it. There were 2 transitions that saw previously extrinsically motivated students become intrinsically motivated, and 3 transitions that saw students who were externally motivated become intrinsically motivated. The changes in means are detailed in Table 12. When looking at the entirety of the unmatched data set ($N_{Pre}=29$, $N_{Post} = 16$) the RAI increased from 0.67 to 1.62.

N	Mean Pre $\pm$ Standard Deviation	Mean Post $\pm$ Standard Deviation	Δ
12	1.73 $\pm$ 1.69	1.26 $\pm$ 2.31	-0.48

Table 12 - Changes in RAI means between groups

For comparison purposes, it was found that Sri Lankan secondary students had an RAI of 0.82, and Norwegian secondary students had an RAI of 0.62 (Rajapakse Mohottige, 2016). The differences between the two groups were noted by the author to not be statistically significant. It was found that the RAI of three groups of Dutch 9th graders before a semi-online STEM course that hoped to build student autonomy were -0.06, -0.22 and -0.21 respectively (Kroes, 2021). It was found that the RAI of Irish teenagers using the SRQ-A was -0.71, -0.58, and 0.25 in the three groups studied (Sisamakris, 2006). Upon looking at this and comparing to this study's own sample group, there is a group of highly intrinsically motivated students entering the STEM@University programme.

Ünlü (2016) has argued that the RAI has been designed "*without taking into account the fact that intermediate motivation types may generally represent a mixture of internal as well as external motivation.*" He has proposed an alternative method of weighting the RAI to account for this; however, the SRQ-A and RAI were used in their original form.

N=12	Mean Pre $\pm$ Standard Deviation	Mean Post $\pm$ Standard Deviation	Δ
External	2.82 $\pm$ 0.63	2.89 $\pm$ 0.68	0.07
Introjected	3.19 $\pm$ 0.61	2.95 $\pm$ 0.77	-0.23
Identified	3.75 $\pm$ 0.28	3.62 $\pm$ 0.43	-0.12
Intrinsic	3.40 $\pm$ 0.23	3.17 $\pm$ 0.53	-0.24

Table 13 - Changes in motivational subscales means between groups

5.3.1.1 External Regulation

	Improve/Disimprove					
Question	+3	+2	+1	-1	-2	-3
Why do I do my homework? Because I'll get in trouble if I don't.	-	-	1	1	-	-
Why do I do my homework? Because that's what I'm supposed to do.	-	-	1	2	-	-
Why do I work on my classwork? So that the teacher won't yell at me.	-	-	6	-	-	-
Why do I work on my classwork? Because that's the rule.	-	1	3	1	1	
Why do I try to answer hard questions in class? Because that's what I'm supposed to do.	-	2	3	1	1	-
Why do I try to answer hard questions in class? Because I want the teacher to say nice things about me.	-	1	-	2	-	3
Why do I try to do well in school? Because that's what I'm supposed to do.	-	1	1	4	-	-
Why do I try to do well in school? Because I will get in trouble if I don't do well.	-	-	2	4	-	-
Why do I try to do well in school? Because I might get a reward if I do well.	-	1	-	2	-	2

Table 14 - Changes in External Regulation

Analysis of the increases in external regulation were seen across questions relating to classwork and hard questions. Six out of the twelve participants reported being increasingly motivated to complete their classwork under the fear of their teacher yelling at them as they shifted their answers up by 1 point on the 4-point Likert scale. There were also noticeable changes in the “*Why do I try to answer hard questions in class? – Because that’s what I’m supposed to do*”.

Decreases in external regulation were noted in all three questions related to doing school work well.

5.3.1.2 Introjected Regulation

	Improve/Disimprove					
Question	+3	+2	+1	-1	-2	-3
Why do I do my homework? Because I want the teacher to think I'm a good student.	-	1	1	4	1	-
Why do I do my homework? Because I will feel bad about myself if I don't do it.	-	-	1	2	1	-
Why do I work on my classwork? Because I want the teacher to think I'm a good student.	-	-	2	5	-	-
Why do I work on my classwork? Because I'll be ashamed of myself if it didn't get done.	-	-	1	2	-	1
Why do I try to answer hard questions in class? Because I want the other students to think I'm smart.	-	2	2	1	3	-
Why do I try to answer hard questions in class? Because I feel ashamed of myself when I don't try	-	-	2	3	3	1
Why do I try to do well in school? So my teachers will think I'm a good student	-	1	2	4	1	2
Why do I try to do well in school? Because I'll feel really bad about myself if I don't do well.	-	-	2	1	1	-

Why do I try to do well in school? Because I will feel really proud of myself if I do well.	-	1	3	1	-	-
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Table 15 - Changes in Introjected Regulation

Upon looking at changes in questions related to introjected regulation, there were noticeable decreases in 5 questions, 1 related to homework, 2 related to classwork, 1 related to hard questions and 1 related to doing school work well. This does tally with the slight decrease overall noted in introjected regulation.

5.3.1.3 Identified Regulation

	Improve/Disimprove					
Question	+3	+2	+1	-1	-2	-3
Why do I do my homework? Because I want to understand the subject.	-	-	2	3	-	-
Why do I do my homework? Because it's important to me to do my homework.	-	1	1	2	-	-
Why do I work on my classwork? Because I want to learn new things.	-	-	1	1	-	-
Why do I work on my classwork? Because it's important to me to work on my classwork.	-	-	1	4	-	-
Why do I try to answer hard questions in class? To find out if I'm right or wrong.	-	-	1	1	-	-
Why do I try to answer hard questions in class? Because it's important to me to try to answer hard questions in class.	-	-	1	4	-	-
Why do I try to do well in school? Because it's important to me to try to do well in school.	-	-	-	3	-	-

Table 16 - Changes in Identified Regulation

There were 3 questions which noticeably decreased in this section, 1 related to classwork, 1 related to hard questions and 1 related to trying to do well in school.

Both “*Why do I work on my classwork? - Because it’s important to me to work on my classwork*” and “*Why do I try to answer hard questions in class? - Because it’s important to me to try to answer hard questions in class.*” saw 4 students decrease their answer by 1 compared to 1 who increased it by 1. “*Why do I try to do well in school? - Because it’s important to me to try to do well in school.*” saw three students decrease their answer by 1.

5.3.1.4 Intrinsic Motivation

Question	Improve/Disimprove					
	+3	+2	+1	-1	-2	-3
Why do I do my homework? Because it’s fun.	-	1	1	4	-	-
Why do I do my homework? Because I enjoy doing my homework.	-	-	1	3	1	-
Why do I work on my classwork? Because it’s fun.	-	-	1	2	-	-
Why do I work on my classwork? Because I enjoy doing my classwork.	-	-	-	3	-	1
Why do I try to answer hard questions in class? Because I enjoy answering hard questions.	-	-	2	2	1	-
Why do I try to answer hard questions in class? Because it’s fun to answer hard questions.	-	-	2	4	-	-
Why do I try to do well in school? Because I enjoy doing my school work well.	-	-	1	3	-	-

Table 17 - Changes in Intrinsic Motivation

There were overall decreases across all questions in this subscale, but there were 2 noticeable changes within 1 question relating to homework and 1 question relating to classwork. “*Why*

do I do my homework? - Because I enjoy doing my homework” saw 3 students reduce their scores by 1 point, 1 by 2 points compared to 1 student who increased it by 1.

“Why do I work on my classwork? - Because I enjoy doing my classwork.” saw 3 students reduce their scores by 1 point and 1 by 3 points.

5.3.2 Summary of Autonomy findings

When students entered STEM@University, they reported a high RAI compared to other groups which were detailed in Section 5.3.1. These students entered the programme already comparatively highly motivated compared to students who might not self-nominate to participate in an online STEM course. It should be noted that there wasn’t a significant decrease in students’ RAI from when they entered STEM@University.

While the instrument is intending to pick up items exclusively related to students’ time at STEM@University, it is inevitable that it will measure some things that outside of the realm of STEM@University. For example, the increase in students reporting that they are motivated to complete their classwork because they do not want their teachers to yell at them.

Decreases in introjected regulation are welcome and would indicate that students are motivated for themselves and not because of others. The 7 students shifting indicating that they are less motivated by teachers saying nice things, or so that teachers will think that they are good students might be a specific response to the autonomous and self-regulated nature of the course.

Overall decreases across many questions in intrinsic motivation are interesting, especially the shifts in relation to *“enjoying”* work. These do not match what was described within the focus groups and this will be discussed at a later stage.

One of the key objectives of STEM@University was to develop student autonomy and to examine if STEM@University was a conducive environment for developing autonomy. To ascertain this, it had been planned within the focus group facilitation plan to prompt students with autonomy before the ranking exercise if they had not previously identified it themselves as detailed in Section 3.4.6.

During the focus group, students self-identified autonomy characteristics, and referred to this in terms such as *“Independent Learning”* or *“Ownership of Learning.”*

“I don’t know how to put this in a skill but kinda, Ownership of Learning, because we were sent the lectures every Tuesday and it was up to us to finish them and understand them, or we have our live classes on the Thursday so that like sense of ‘You need to get it finished, and if you don’t understand one section well you go off and you do your own research and try and understand it as best you can’” – Lucy.

“I definitely agree with Lucy in the sense that I definitely got better at working independently which will be really useful. You know they gave you the lectures, you had to do them, otherwise you weren’t going to understand the live lesson and you were working with your own initiative which will be really useful when it comes to college.” – Niamh.

When asked to rank the skills and attributes developed which they self-described, 3 out of the 4 students chose *“Independent Learning”* as the skill which developed the most. When asked to justify their ranking, students chose aspects which mainly might be identified as increasing independent regulation.

“If you didn’t watch the lectures, like there was nobody there to tell you that you had to watch them. The artefact as well, if you didn’t do it, they wouldn’t like scold you or anything like that. You just took it upon yourself to do it, it was very different to secondary school.” – Daniela.

“Similar to Niamh and Daniela, you weren’t going to get reprimanded if you didn’t do it, no one was going to send a letter home or ring home or anything like that. You were there because you wanted to be there and you wanted to work to find out more.” - Edward.

The student who didn’t rank *“Independent Learning”* or *“Ownership of Learning”* as being their number 1, has the following to say on the topic.

“The reason I put it number 3 and report writing is number 1 is, Ownership of Learning, I experienced that for the first time when we had to study for the Junior Cert during quarantine. In our school the teachers gave us the work that they wanted us to get

done. There wasn't any pressure, they just told us that it would be good if you could get these things done and that was something that I enjoyed, that ownership of learning...In the STEM course it was the exact same and I really enjoy that style of learning, where you get to decide when you finish the lectures and it's upon to yourself to do it" – Lucy.

But as the discussion continued some students did identify the value of increasing amounts of intrinsic motivation in comparison to being extrinsically motivated.

"That in itself kinda brings out a higher quality of work because you know that if you are interested in it that you can provide the next step. You know, if you're in school and you're in a Geography class and you don't like Geography, you're not going to give that what you fully can. You're just going to do it to get it fully done, compared to here, where you wanna do it and you wanna do it well because you find it interesting and you wanna prove to yourself that you can do it well." – Edward.

Features to facilitate this in the artefact were perceived by the students, such as choice and lack of external autonomy thwarting influences.

"I did other online courses and there wasn't much independent work, like the artefact. It allowed me, and encouraged me to do further research on the topic, to be more creative about it in my own interpretation." – Niamh.

'If I had to pick a favourite one I think I'd pick the stress and strain one was really interesting because I really liked doing the artefact for that one, creating your own problem and see who was at fault it was, that was really interesting for me" – Lucy.

"If you didn't watch the lectures, like there was nobody there to tell you that you had to watch them. The artefact as well, if you didn't do it, they wouldn't like scold you or anything like that. You just took it upon yourself to do it, it was very different to secondary school." – Daniela.

While initially when discussing the topic students were highly focused on the value of what they were doing, focussing their independent learning within the identified motivation subscale, there were many instances of students discussing of enjoyment or excitement which would indicate intrinsic motivation amongst these students.

“It was good to figure out which parts of STEM really excited me” – Niamh.

“I really liked the artefacts, they were fun” – Niamh.

“To do a course like this, where I actually enjoyed being independent, working independent, and I just think it was really important for me to figure out that it was not that scary and it was actually enjoyable and it does work with a lot of people.” – Niamh.

“I found the artefacts to be something different, like a creative spin on what you were doing. Like there was one, attracting an alien to come to earth. That was a really fun way of learning more. All the topics that we covered in the lectures were really interesting, I really loved learning about them cause they were all interesting topics and they were done was really interesting” – Daniela.

“..then I signed up for the second module, and really enjoyed it” – Lucy.

“We didn’t do a lot of physics for the Junior Cert, but I liked math. They’re similar in ways, it’s kinda applied math with theory so I enjoyed it in that respect. But I think if I could go back and do my subjects out, I’d think about doing physics more.” – Edward.

5.4 STEM Identity

In research question number 2(d), the question asked what the student experienced during their time on the course. To answer this question to the best of the researcher’s ability, the data relating to each individual person who completed both the pre- and post-questionnaires have been compiled into a case study.

Case studies have been used previously to document student identity development within STEM (Archer et al., 2021; Carlone & Johnson, 2007; Luce & Hsi, 2015) while both quantitative and qualitative data has been previously used to build a picture of a students’ science identity (Carlone, 2004). Both quantitative and qualitative data will be contained in each case study in an effort to portray a more holistic image of each individual’s journey (Brown, 2008). Each case study will include an overview of the individuals changes in STEM capital, self-efficacy and relative autonomy index score (presented as radar diagrams), their individual responses to the specific statements in the questionnaires as well as their reflection sheets and artefacts to capture their experience over the six weeks.

After all case students are individually presented, a summary table highlighting each student's development of STEM capital, sources of science self-efficacy and RAI will be used to view all the captured variables side by side and highlight the changes within their STEM trajectories.

The quantitative data has been normalised on a scale from 0 to 1, allowing for shifts to be compared alongside some of the others.

As outlined in Sections 5.1, 5.2, and 5.3, these students have high amounts of STEM capital and sources of science self-efficacy compared to the general student population as well as being more autonomously motivated than the general student population. This should be considered as the normalised data is presented. A low score presented on the normalised scale isn't compared to a wider sample of student data.

In Section 2.1.3 the reasoning is presented why this study is measuring student STEM capital, sources of science-self-efficacy and autonomy development as being key contributing factors to their STEM identity development and an indicator of their trajectories within STEM.

5.4.1 M2A8 – Teresa

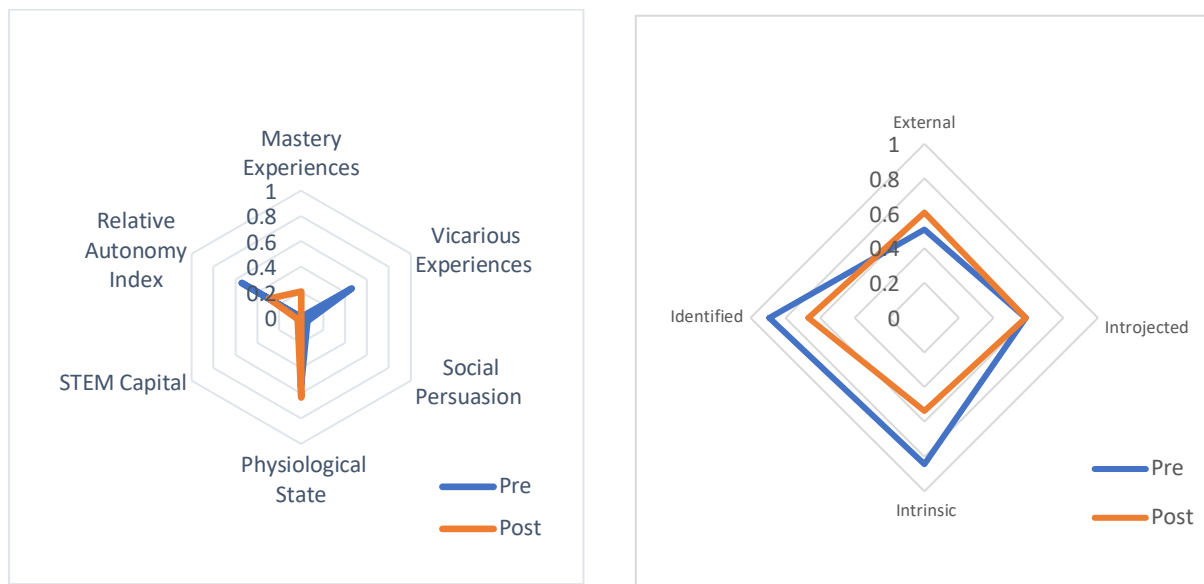


Figure 9 - (a) Teresa's Overall Changes, (b) Teresa's Motivational Changes

Teresa signed up for Module 2 of STEM@University. When Teresa signed up, she said that she *“was hoping (that she) would gain an insight into what it’s like to study in the area of STEM in college.”*

Teresa spent 2.5 hours on Assignment 1. She deemed herself to be successful and said that she wanted to spend the same amount of time on the next assignment.

When asked what mark she would award her artefact out of 10 she said,

“I would give myself a 7 out of 10 because I think I did a successful report but there were areas to improve on.”

While her STEM capital increased overall from 42.58 to 43.56, her scores suffered from perceived external influences as both of the following questions changed from *“Agree”* to *“Neutral”*.

- One or both of my parents have explained to me that science is useful for my future.
- My teachers have specifically encouraged me to continue with science subjects after my Junior Cycle.

Teresa also said she talked to more people before STEM@University compared to after as at the beginning of the course, she said she spoke to siblings and extended family members. However, during the course it seems that she is aware of a sibling who has begun working in

science. Positively, Teresa's answers changes from "*Never*" to "*Once a Year*" for the following questions.

- When not in school, how often do you read books or magazines about science?
- When not in school, how often do you go to a science centre, science museum, or planetarium?

In the sources of science self-efficacy scale that is scored from a Definitely False to a Definitely True in 6 unlabelled increments, the increase in mastery from 4.33 to 4.67 was accounted for as Teresa gave herself a 5 instead of 4 instead for "*I have always been successful with science*" and "*I got good grades in science on my last report card*". She also moved from a 2 to a Definitely False on "*Even when I study very hard, I do poorly in science*" and from a 3 to a 4 on "*I do well on even the most difficult science assignments*". These outweighed shifts of 5 to 4 in "*I make excellent grades on science tests*" and "*I do well on science assignments*".

The shift in vicarious experiences from 4.83 to 3.83 is because of a change from Definitely True to 4 in "*When I see how my science teacher solves a problem, I can picture myself solving the problem in the same way*" and a 5 to 3 in "*Seeing adults do well in science pushes me to do better*". There was an increase in Teresa's science self-efficacy sourced from physiological states from 5.17 to 5.33 because of the reverse coded "*Just being in science class makes feel stressed and nervous*" moving from a 3 to a 2.

During Teresa's time at STEM@University, her RAI decreased from 2.33 to 0.46 due to a fall in her intrinsic motivation and a rise in her extrinsic motivation. Contributing to her rising extrinsic motivation were items such as "*Why do I do my homework - So that the teacher won't yell at me.*" Moving from "*Not Very True*" to "*Sort of True*" and "*Why do I do my classwork - Because that's the rule.*" Moving from the extreme "*Not at all True*" to "*Very True*".

Teresa's fall in intrinsic motivation can be accounted for by questions such as "*Why do I do my homework - Because I enjoy doing my homework.*" moved from a "*Sort of True*" to "*Not at all True*" and "*Why do I try to answer hard questions in class - Because it's fun to answer hard questions*" moving from "*Very True*" to "*Sort of True*".

While decreases were seen in some attributes that STEM@University hoped to increase, by examining the factors that led to the decreases it seems that some of these might be outside

of the realm of STEM@University; however, it is noted that there were falls in the scoring relating to the fun of answering hard questions. It is the opinion of the author that this question should relate strongly to intrinsic motivation at STEM@University.

Self-reported small increases in STEM capital, Mastery experiences and physiological state are good. It is possible that these increases are a result of Teresa feeling that STEM in college might be for her and that the fear of studying what could be seen as an intimidating subject is lessened.

5.4.2 LOJ10 – Karen

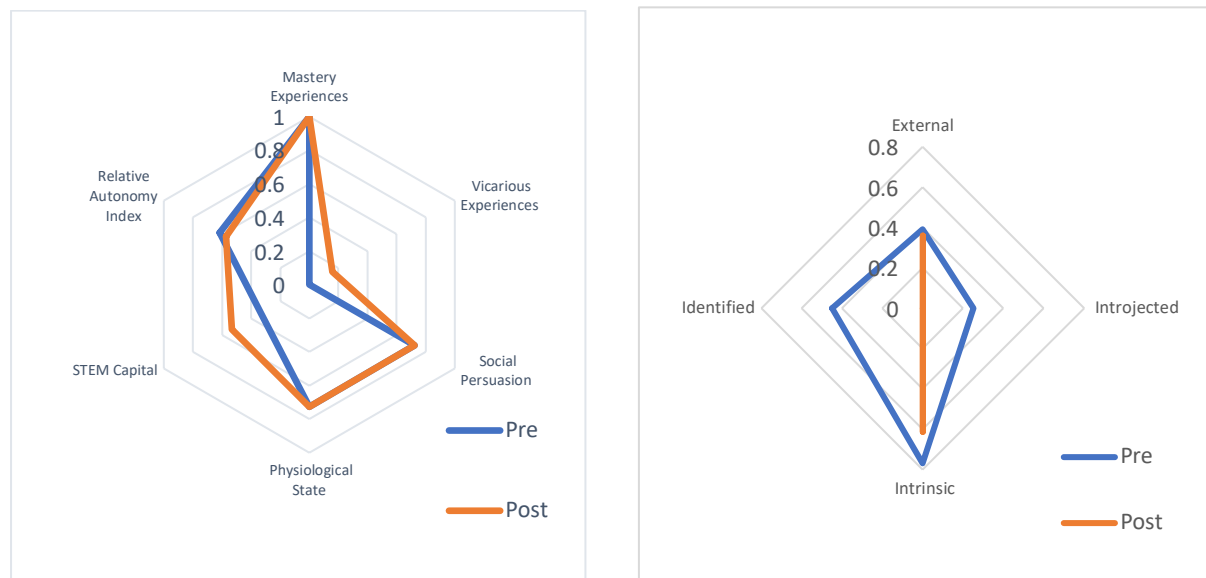


Figure 10 - (a) Karen's Development Overview, (b) Karen's Motivational Changes

Karen signed up for Module 2 of STEM@University. When she signed up, she was looking for "Third level experience". Karen didn't submit any reflection sheets to accompany her artefacts.

Her increase in STEM capital from 52.48 to 58.42 is seen within questions that it would be hypothesised that STEM@University would influence. After participating in the course, Karen strongly agrees that she can use scientific evidence to make an argument and reports talking more often to the people around her about science.

Increases in efficacy sourced through vicarious experiences from 3.83 to 4.17 can be accounted for by changing answers in "When I see how another student solves a science problem, I can see myself solving the problem in the same way", as Karen changed her answer

from a 3 to a 5 on the 6 point scale, in *“When I see how another student solves a science problem, I can see myself solving the problem in the same way”* when her answer changed from a 4 to a 5 and *“When I see how my science teacher solves a problem, I can picture myself solving the problem in the same way”* as Karen moved from a 3 to a 5. These outweighed other changes within the Vicarious Experiences section of the sources of science self-efficacy Scale; *“I compete with myself in science”* went from a 6 to a 5, and *“Seeing kids do better than me in science pushes me to do better”* went from a 4 to a 2.

Within the SRQ-A, there were decreases in various questions relating to many sources of work and many sources of motivation. Of note within the SRQ-A is that Karen still enjoys answering hard questions and thinks that it is fun to answer hard questions. Within the questions relating to STEM@University *“Why do I sign up for extra-curricular educational activities (like STEM@University)?”*, Karen was consistent in responding *“Very True”* before and after the programme to *“Because It’s Fun”* and *“Because I enjoy a challenge”*.

I think it can be deduced that this was a positive experience for Karen. While attending the course, Karen’s rise in STEM capital and rise in vicarious experiences could possibly come from her being exposed to new role models and experiences within STEM. Even though her RAI remained relatively constant, a decrease was seen in all the subscales contributing to it. The questions of interest to us that could possibly relate to her intrinsic motivation in STEM@University remained unchanged.

5.4.3 AOP5 – Daithi

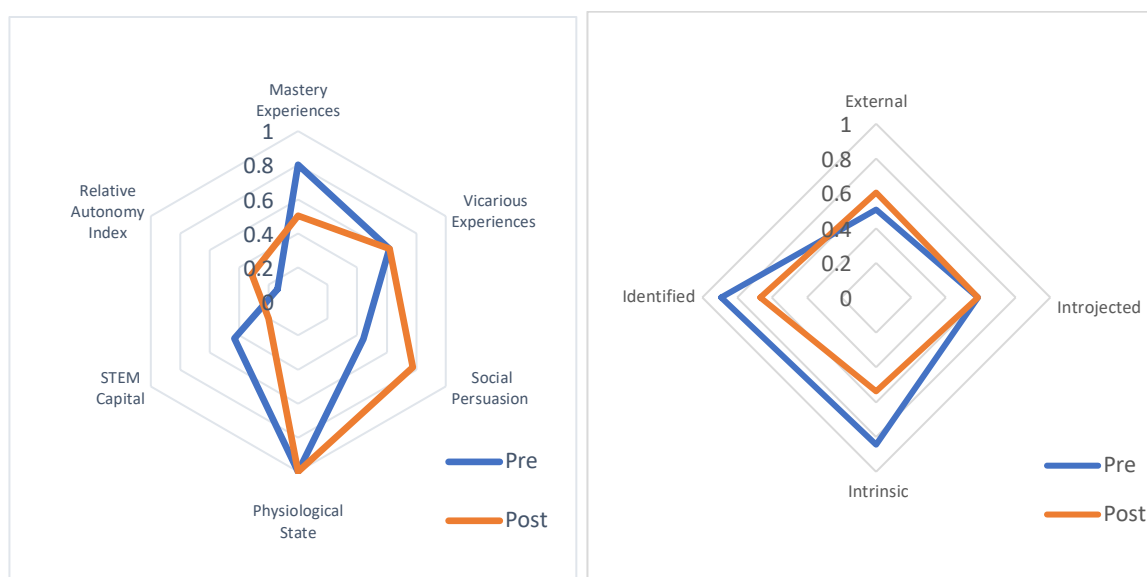


Figure 11 – (a) Daithi's Development Overview, (b) Daithi's Motivational Changes

Daithi signed up for Module 2 of STEM@University. When he signed up, he stated that he wanted to get *"A taste in an engineering course"*.

Daithi spent 1 hour on Assignment 3. He deemed it as being a successful assignment and felt that he did a good job *"Presenting the Maths Well"*. He scored himself a *"7, as it was good but could be better"*.

The decrease in STEM capital from 55.56 to 48.51 has taken place as Daithi has noted that he is speaking to other people about science and reading about science less often. A shift from *"Agree"* to *"Neutral"* is also seen within *"My teachers have explained to me science is useful for my future"* and *"It is useful to know about science in my daily life."*

Daithi's physiological state from his sources of self-efficacy is at the maximum value for both before and after the STEM@University programme as he answered the maximum scoring answer to all 6 items in both questionnaires. It's obvious that he is never stressed or overwhelmed by the thought of science.

While there was a negative shift in mastery experiences from 5.67 to 5.17, this is largely accounted for by two questions that went from a 6 to a 5 in both *"I do well on Science Assignments"* and *"I do well on even the most difficult science assignments"*. Daithi's social persuasion score moved from 4.33 to 5.33, indicating that attending the STEM@University programme has provoked some external praise of his abilities from others. *"Adults in my*

family have told me what a good science student I am” moved from 5 to 6 while *“I have been praised for my ability in science”* and *“Other students have told me that I’m good at learning science”* moved from a score of 4 to 6.

Daithi’s increase in RAI is accounted for by his decreasing amounts of extrinsic and introjected motivation. This is reflected by his changing answers to *“Why do I answer hard questions – Because I want the other students to think I’m smart”* which changed from a *“Very True”* to *“Not Very True”* and *“Why do I answer hard questions – Because I want the teacher to say nice things about me”* which changed from *“Very True”* to *“Not at all True”*. While his intrinsic motivation also decreases, this is because of negative changes to relating to his classwork. The response shift from *“Sort of True”* to *“Not Very True”* on the items *“Because it’s fun”* and *“Because I enjoy doing my classwork”* are noted. Items relating to the fun or enjoyment of both answering hard questions or attending courses like STEM@University remain in the maximum values of intrinsic motivation before and after the programme.

It’s clear that Daithi is someone who values the long-term benefits that education can bring and is comfortable within the world of science. Was his change in mastery experiences part of an awakening that more challenging material exists for him to engage with, and this was prompted by increasing challenges given to him by STEM@University? Given his increases in social persuasion and decreases in STEM capital, could the question be asked as to whether Daithi is uncertain about his future in STEM? He knows that he can do it, but maybe he likes to learn in other subjects as well. Being a teenager is tough, and Transition Year is a time of reflection and big questions for students relating to subject choice, career choice and what they want in life.

5.4.4 JO15 - Bríd



Figure 12 - (a) Bríd's Development Overview, (b) Bríd's Motivational Changes

Bríd signed up for Module 2 of STEM@University as she *"hoped to gain a knowledge of what I like and am interested in so I know what subjects I should take for the years to come. I also wanted to learn more about STEM areas."*

For Assignment 2, Bríd spent 3 hours on it and said she wanted to spend the same amount of time on it. She deemed herself successful. When asked to grade herself she *"would give myself an 9 because my delivery system wasn't entirely correct and because I couldn't find a diagram for the respiration system."*

Decreases in Bríd's STEM capital score from 60.39 to 53.47 come from her reporting that she speaks to other people less often about science and isn't reading science magazines and books as often. While she has increasing appreciation of the different types of job one can get with a science degree as this has moved from Agree to Strongly Agree, she feels that is less useful to know about science in her daily life as this has moved from Strongly Agree to Agree and feels that her teachers aren't as encouraging to her to continue studying science subjects in Senior Cycle. This has changed from Agree to Neutral.

A decrease in mastery experiences from 5.5 to 5.17 is slight but accentuated in this radar plot due to the normalization process. These slight changes are accounted for by Bríd's view on *"I make excellent grades on science tests"* and *"I got good grades in science on my last report card"* going from a 6 to a 5. Bríd's decrease in vicarious experiences largely comes from

questions relating to the vicarious experiences sourced from herself. Both *“I imagine myself working through challenging science problems successfully”* and *“I compete with myself in science”* moved from 5 to 4. It is seen that Bríd’s social persuasion scores decrease in 4 out of the 6 items by one movement on the 6-point Likert scale. While for physiological state, Bríd reported low levels of stress when she was doing her science work. Upon beginning STEM@University, she reported a 3 out of 6 for *“I start to feel stressed-out as soon as I begin my science work”* and *“My mind goes blank and I am unable to think clearly when doing science work”*, the small decrease in physiological state is accounted for Bríd reporting a 2 in the Post-Questionnaire for *“My mind goes blank...”*.

The RAI decrease from 2.49 to 1.13 has arisen due to increases in Bríd’s external motivation but also indicates that Bríd is still intrinsically motivated overall. There were increases in both *“Why do I do work on my classwork? - So that the teacher won’t yell at me”* and *“Why do I do work on my classwork? - Because that’s the rule”* from *“Not Very True”* to *“Sort of True”*. Designed questions relating to intrinsic motivation specifically at STEM@University received the same *“Very True”* response before and after the programme.

Decreases in STEM capital and mastery experiences are on the face of it largely out of the control of factors that STEM@University can influence and the increase in Bríd’s physiological state indicates that she is more comfortable working within science. It’s disappointing that Bríd’s vicarious experiences dropped, but it should also be noted that 2 of the items relating to vicarious experiences from others did increase. Increases to Bríd’s external motivation cannot be attributed to her time at STEM@University but are more likely to come from her time in formal education.

Bríd came to STEM@University to see if she liked STEM or not, and like Daithi she is looking for an experience that guide her in the future. Could an increase in Bríd’s self-efficacy sourced from her physiological state be enough to turn her into a STEM student in the future?

5.4.5 DOX8 – Eibhlín



Figure 13 - (a) Eibhlín's Development Overview, (b) Eibhlín's Motivational Changes

Eibhlín registered for Module 2 of STEM@University. She signed up for the course as she wanted to get “An insight into what it is like to be a STEM student in Trinity”.

When she signed up for the course, she expressed that she had a good understanding of what was expected of her in college, that she could supplement her own learning, that she was able to reflect on her learning and that she was confident communicating in an online environment. She was unsure on whether she felt prepared to succeed in third level and sufficiently prepared to learn online. In the pre-questionnaire, Eibhlín presented the highest STEM capital of any of the students that will be presented. From her SRQ-A, it can be ascertained that she was intrinsically motivated.

Eibhlín completed all the assignments and self-assessment tasks in the course.

Eibhlín self-reported spending over 4 hours completing her first assessment, Unique Methods of Calculating Pi. She completed the self-assessment reflection sheet giving her herself an 8 out of 10 and felt she was successful in completing the brief.

“I would give myself an 8 as I could have experimented with more of the methods myself and added a little more creativity to the assignment; I think in terms of meeting the criteria my report was successful but a little more originality would have made it exemplary”

For assignment 2, she completed her Prezi. Despite saying she'd like to spend more time on this assessment, she once again logged spending 4 hours on it. She graded herself as being successful and gave herself *"8 as it was a very good job for my first Prezi"*.

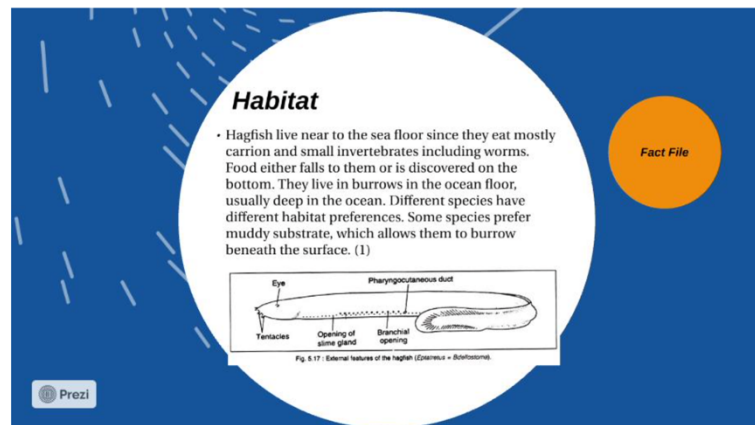


Figure 14 - Example of Eibhlín's Artefact

In the final assignment, she spent 2 hours on it. She deemed herself successful but only gives herself a *"6 or 7 as I didn't spend as much time on this Artefact as the other two"*.

The amount of time spent completing the artefacts collates with her increase in intrinsic motivation throughout the course. While she spent large amounts of time on them, she always felt should be doing more to make her work worthy of being exemplary.

Eibhlín already had a lot of STEM capital before attending STEM@University. Her drop from 72.28 to 67.33 in STEM capital could be attributed to the changing living conditions during life in March and April 2021 in the second wave of the COVID-19 pandemic. Despite the drop, *"I know how to use scientific evidence to make an argument"* improved from *"Agree"* to *"Strongly Agree"*.

Her mastery experiences increased because of some factors which could be attributed to STEM@University and some that can't. *"I do well on even the most difficult science assignments"* increased from 4 to 5 and *"I do well on science assignments"* moved from 5 to 6, while externally *"I got good grades in science on my last report card"* also moved from 5 to 6.

The shift in vicarious experiences was exemplified by the increase in *“When I see how another student solves a science problem, I can see myself solving the problem in the same way”* increase from 4 to 6. It should be noted that *“I imagine myself working through challenging science problems successfully”* moving from 5 to 3 could be indicator of the new level of challenges experienced within the course.

Increases in social persuasion as being a source of science self-efficacy align with her answers relating to the high amounts of communication with others about science in the STEM capital aspect of the questionnaire. *“People have told me that I have a talent for science”* and *“I have been praised for my ability in science”* moved from 4 to 5.

Eibhlín also has very little negative connotations associated with science according to the physiological state subscale, and it was seen that at the end of the course she reported the highest possible answer for this. Answers to: *“Just being in science class makes feel stressed and nervous”*, *“Doing science work takes all of my energy”* and *“I start to feel stressed-out as soon as I begin my science work”* all moved from 2 to 1.

All of these contribute to a student who enjoys science and enjoyed participating in a course that gave them an opportunity to discuss science with the people immediately around them. Eibhlín was a highly motivated student with large amounts of STEM capital before she started the STEM@University programme. It’s encouraging to see her more confident in using scientific evidence to make an argument.

5.4.6 LOG3 – Aoife



Figure 15 - (a) Aoife's Development Overview, (b) Aoife's Motivational Changes

Aoife completed Module 3 only. When she signed up for STEM@University she stated that she signed up so that she could obtain *“A better understanding of how STEM courses would be taught in third level education and also to gain a better understanding for Leaving Certificate”*.

She reported spending 0.5 hours on Assignment 1 in an assignment on Stellarium.

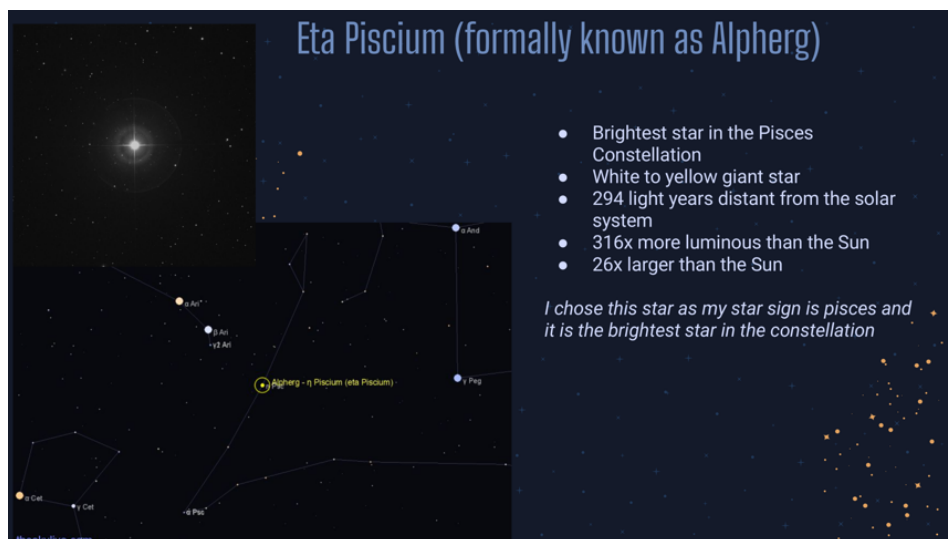


Figure 16 - Example of Aoife's Artefact

She deemed herself successful and gave herself a score of *“7/10 - I could have included more detail on the facts I gave”*.

In Assignment 2, Aoife completed a hand drawn poster on Earth. It took her 3 hours and she deemed herself successful. When it came to grading herself out of 10, Aoife said she deserved an “8 - I hand drew it and felt that I used a lot of graphics”.

In the third and final assignment, Aoife completed an assignment on Drag in Swimming. There was no self-assessment sheet issued for this assignment.



Figure 17 - Example of Aoife's Artefact

When Aoife entered STEM@University, it could be argued that she was a student who could represent the median student at STEM@University across the quantitatively measured attributes.

It's disappointing to see her STEM capital fall from 58.42 to 49.50 during the course; but some of this (ie. Questions relating to parents and teachers) can be attributed to aspects that are out of the control of the STEM@University module. Her feelings changed on “I know how to use scientific evidence to make an argument” and “It is useful to know about science in my daily life”, as they both fell from “Strongly Agree” to “Agree.”

She got the opportunity to increase her mastery experiences during the course from 5.17 to 5.33 but saw decreases in her self-efficacy obtained from vicarious experiences. Did the module contain enough appropriate amounts of ways for this to increase for her? “When I see how my science teacher solves a problem, I can picture myself solving the problem in the same way” moved from 6 to 4 and “When I see how another student solves a science problem, I can see myself solving the problem in the same way” moved from 5 to 3.

Her move from a person who is intrinsically motivated to one who is extrinsically motivated is one that aligns with the time spent on artefact 1 of only 0.5 hours. “Why do I try to answer hard questions in class? - Because I enjoy answering hard questions” and “Why do I try to

answer hard questions in class? - Because it's fun to answer hard questions" both moved from *"Sort of True"* to *"Not Very True"*.

Aoife came into the course with identified motivation to answer questions relating to her own future. Transition Year is a time for reflection and decision making for students (Smyth & Calvert, 2011). While you may see the shift in intrinsic motivation amongst other things and say that the course turned her from the idea of STEM in the future, she still categorised attending STEM@University because it's fun as being *"Sort of True"*. Is receiving answers about your own future, probing what might be involved and still thinking it is sort of fun a terrible idea if certain measurables shift?

5.4.7 I1P4 – Eoin

Eoin signed up for Module 2 of STEM@University. When he signed up, he stated that he wanted *"To gain a greater understanding of STEM and perhaps get an indication as to what lectures in university are like!"*.



Figure 18 - (a) Eoin's Development Overview, (b) Eoin's Motivational Changes

He spent 2.5 hours on Assignment 1 and felt that a bit less time was needed. He deemed himself successful on the Assignment. He gave himself an *"8 as I feel I was successful in compiling a decent scientific report yet I personally think I perhaps could have done a little bit more to ensure I had included all aspects of the scientific report in greater detail."*

"Notwithstanding the fact that this approximation was quite accurate in regard to π , it must be said that the way in which I measured the diameter (with a ruler at first)

indeed left margin for error as I could not be fully sure whether or not it ran straight through the centre as the diameter does, or if I was slightly out. I think the use of the vernacular calliper (sic) aided in ensuring the measurement was relatively accurate, but I also must acknowledge that the width of the rim of the mug, could possibly have added a small amount to the measurement perhaps making it a little inaccurate. I believe my using of the circumference of a circle formula in conjunction with a calculator left little margin for error.” – Extract from Eoin’s Artefact 1

For Assignment 2 he worked on it for 3 hours. Once again, he felt that less time was needed and deemed his assignment as Successful. He scored himself an 8 on the assignment.

During his time at STEM@University, an increase was seen in Eoin’s STEM capital as it moved from 50.49 to 58.42. He saw the value a that science qualification can add to get many different types of job as this moved from Agree to Strongly Agree and he is more often is talking to people about science and engaging with science reading material.

Eoin reported the highest mastery experiences possible on all the items in the pre and post questionnaires.

Growth was reported in the vicarious experiences section as there was an overall shift from 5 to 6. This is categorised by increases from 5 to 6 in *“Seeing kids do better than me in science pushes me to do better”*, *“When I see how another student solves a science problem, I can see myself solving the problem in the same way”* and *“When I see how my science teacher solves a problem, I can picture myself solving the problem in the same way”*. *“I imagine myself working through challenging science problems successfully”* also moved from a 4 to a 6.

An increase from 5.67 to the maximum of 6 in social persuasion as well as an increase in Physiological State from 5.67 to 5.83 were noted.

An increase was seen in Eoin’s RAI as it moved from -0.02 to 0.81. This shift means that Eoin moved from being extrinsically motivated to being intrinsically motivated during his time at STEM@University. This was due to decreases in extrinsic regulation and introjected regulation. *“Why do I try to answer hard questions in class? - Because I want the other students to think I’m smart”* moved from *“Sort of True”* to *“Not at all True”*.

Eoin's increase in many attributes indicates that his time at STEM@University was fruitful. He wanted to see if STEM was for him and reported increases in STEM capital and science self-efficacy across many sources. He spent considerable time on the artefacts and reflection sheets. It's fair to say that he maximised his time and got the desired rewards from the course itself.

5.4.8 B1P11 – Shauna

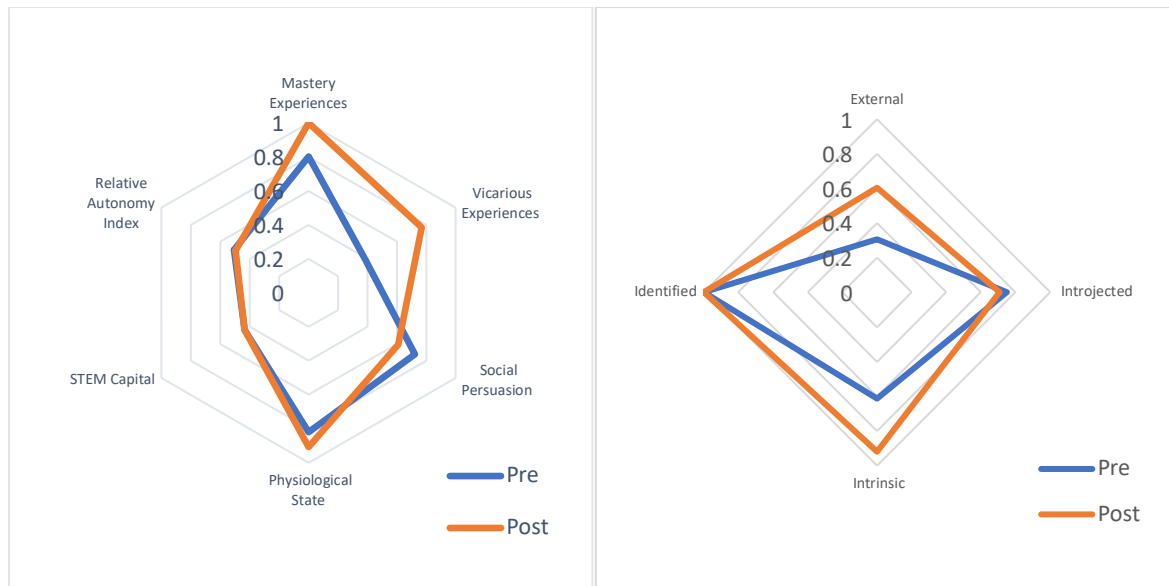


Figure 19 - (a) Shauna's Development Overview, (b) Shauna's Motivational Changes

Shauna signed up for Module 2 as she was looking for *“an insight into what college is about and to help further my knowledge in STEM”*.

She reported spending 3 hours on Assignment 1 and stated that she wanted to spend the same amount of time on the next assignment. She deemed her assignment as being exemplary. She gave herself an *“8.5 (as) I feel like I answered all of the success criteria but the only thing is I could have gone into a bit more debt (detail) on why pi is important in today's world.”*

For her final Assignment 3, she self-reported spending 2 hours on it. Again she deemed her assignment as being exemplary as *“I included great detail in my artefact, told a story and did the maths well”*. She gave herself a grade out of 10 of *“9 - I believe I included everything that was asked of me and met the expectations”*.

Shauna's STEM capital was stayed constant at 55.45 throughout STEM@University. She reported speaking to more people more often about science, but this counterbalanced the shift on *"I know how to use scientific evidence to make an argument"* as it moved from *"Strongly Agree"* to *"Agree"*.

Science self-efficacy sourced from mastery experiences rose from 5.67 to the maximum value of 6. There was also a shift in self-efficacy sourced from vicarious experiences, with positive changes in 4 out the 6 items; including a substantial shift in *"Seeing kids do better than me in science pushes me to do better"* from a 1 to a 4 on the 6-point scale. There were also moves from 5 to 6 in *"I imagine myself working through challenging science problems successfully"* and *"Seeing adults do well in science pushes me to do better"* which indicates that the course influenced Shauna's vicarious experiences.

While Shauna's RAI decreased slightly from 2.06 to 1.98, as there were increases in the extrinsic and intrinsic subscales. Some of these extrinsic changes are exemplified by her feelings on doing her homework because she will get in trouble if she doesn't as this went from *"Sort of True"* to *"Very True"*, while she also feels that she is motivated to do her homework because it's fun changed from *"Not Very True"* to *"Very True"*. There is a large shift in one item in a question related to answering hard questions. Shauna's feelings on answering hard questions because that is what she is supposed to do shifts from one extreme to the other, going from *"Not at all True"* to *"Very True"*, which would also add to the shift in the external regulation.

Shauna is a student who saw her STEM Capital stay constant and her science self-efficacy sourced from mastery experiences, vicarious experiences and physiological state all rise. She wanted to further her knowledge in STEM and judging by the growth in science self-efficacy it's fair to say that did happen.

5.4.9 AOB8 – Amy

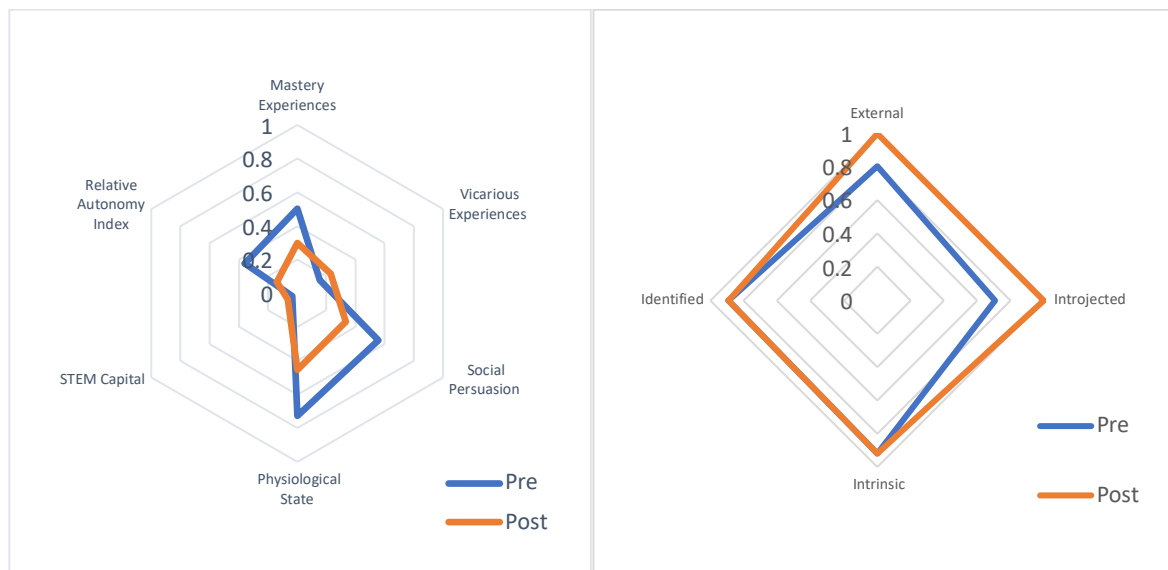


Figure 20 - (a) Amy's Development Overview, (b) Amy's Motivational Changes

Amy signed up for Module 3 of STEM@University as she wanted to gain *“More insight into STEM particularly engineering”*.

She spent 1 hour on assignment 1 and deemed her artefact as being Average. She gave herself a *“7 I taught it was very good but after seeing others it could have been better”*.



Figure 21 - Example of Amy's Artefact

Amy's STEM capital changed from 43.56 to 44.55 throughout STEM@University. There are increases that could be related to STEM@University, e.g. Both *“A science qualification can help you get many different types of job”* and *“It is useful to know about science in my daily life”* changing from *“Agree”* to *“Strongly Agree”* alongside other changes that are unrelated

to STEM@University, e.g. *"My teachers have explained to me science is useful for my future"* changed from a "Disagree" to a *"Strongly Agree"*. Decreases within STEM capital is largely accounted for by Amy less frequently going to science centres or museums and talking with others about science.

Amy's self-efficacy sourced from mastery experiences fell from 5.17 to 4.83, and this is traced back to one change as *"I have always been successful with science"* changed from a 5 to 3 on the 6-point Likert scale. Increases in self-efficacy sourced from vicarious experiences came from *"When I see how my science teacher solves a problem, I can picture myself solving the problem in the same way"* going from a 2 to a 5, *"When I see how another student solves a science problem, I can see myself solving the problem in the same way"* going from a 3 to a 5. These shifts in vicarious experiences from others outweigh the decreases in vicarious experiences from the self, as *"I imagine myself working through challenging science problems successfully"* moved from 5 to 4, and *"I compete with myself in science"* moved from 6 to 5. There were 2 large shifts in social persuasion items, as *"Adults in my family have told me what a good science student I am"* moved from 6 to 3 and *"My classmates like to work with me in science because they think I'm good at it"* moved from 6 to 4.

There was a negative shift in physiological state from 5.5 to 5. There were slight changes in 4 out of the 6 items that balanced each other out, but Amy reported a change from 1 to 4 on *"Just being in science class makes feel stressed and nervous"*.

The movement in Amy's RAI from 0.95 to -0.71 from has come from a change in the extrinsic and introjected directions rather than anything in the intrinsic. Examples of this include *"Why do I do my homework - Because I want the teacher to think I'm a good student"* and *"Why do I try to do well in school - Because I might get a reward if I do well"* moving from "Not Very True" to "Very True". Intrinsic questions relating to her work being fun stayed constant at the "Sort of True" level while there was a small change in the added SRQ-A style question that was asked related to courses like STEM@University as *"Why do I sign up for extra-curricular educational activities (like STEM@University)? - Because I enjoy a challenge"* moved from "Very True" to "Sort of True".

Amy entered wanting to know more about engineering. Maybe the experience answered this for her as there was a decrease in mastery experiences as well as the change in *"Just being in*

science class makes feel stressed and nervous”, even though her overall physiological state still is high at 5. While her STEM capital did increase, maybe science and engineering might not be for Amy.

5.4.10 J1R9 – Erica



Figure 22 - (a) Erica's Development Overview, (b) Figure 23 - Erica's Motivational Changes

Erica signed up for Module 3 of STEM@University. When she signed up she stated that she wanted to use STEM@University for “Meeting new people, and getting a basic knowledge for stem in college.”

Erica didn't complete any reflection sheets related to her assignments.

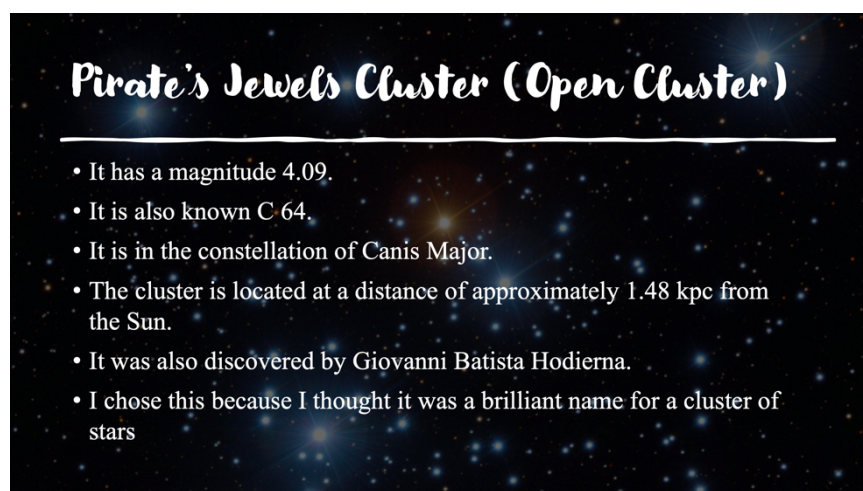


Figure 24 - Example of Erica's Artefact

Over the course of her time at STEM@University, Erica's STEM capital grew from a score of 59.41 to 62.37. Questions that would have contributed to this shift would include *"My teachers have explained to me science is useful for my future"* moving from *"Disagree"* to *"Strongly Agree"* and *"I know how to use scientific evidence to make an argument."* moving from *"Neutral"* to *"Agree"*. There were negative shifts as Erica reports only reading books or magazines about science once a term instead of the previous once a month, and going to science centres, museums or planetariums once a year instead of once a term.

A shift in Erica's science self-efficacy sourced from mastery experiences from 4.67 to 4.33 is demonstrated by changing answers to the reverse coded *"Even when I study very hard, I do poorly in science"* moving from a 2 to 3 and *"I do well on even the most difficult science assignments"* moving from 5 to a 4.

There were changes in 3 out of the 6 items within Erica's vicarious experiences, as it dropped from 4.5 to 4. *"When I see how another student solves a science problem, I can see myself solving the problem in the same way"* moved from a 6 to a 4, while *"Seeing adults do well in science pushes me to do better"* moved from a 5 to a 4. Interestingly, *"I compete with myself in science"* moved from a 1 to a 4.

Increases in Erica's social persuasion came from adults and other students. *"Adults in my family have told me what a good science student I am"* and *"I have been praised for my ability in science"* moved from 4 to 5 while *"Other students have told me that I'm good at learning science"* and *"My classmates like to work with me in science because they think I'm good at it"* moved from 5 to 6.

Erica's physiological state dropped slightly from 4.33 to 4.17. The reverse coded *"Doing science work takes all of my energy"* moved from 4 to 6, which outbalanced the move in *"I start to feel stressed-out as soon as I begin my science work"* from 4 to 3.

For Erica, the increases in her STEM capital from her conversations with adults co-incide with her increases in social persuasion in the sources of science self-efficacy scale. She could have worked hard at the course which *"took all of her energy"*, but the programme gave her the opportunity to discuss her science progress with adults around her. It is possible that she feels more comfortable in science after these conversations given that she reports being *"less stressed-out"*, but this has led to her being more extrinsically motivated.

5.4.11 R0M11 – Josephine

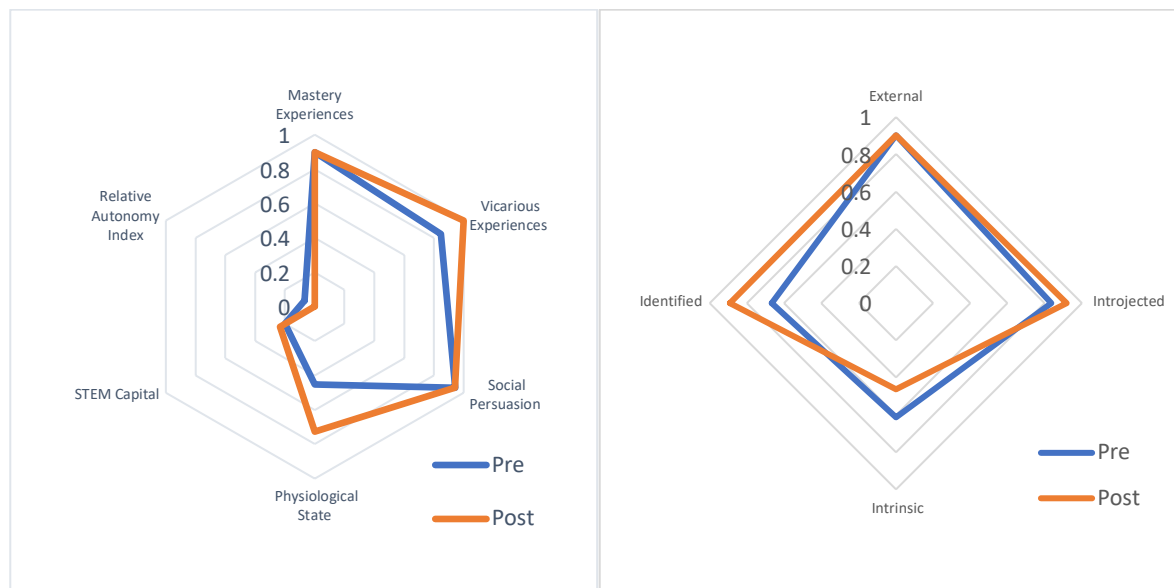


Figure 25 - (a) Josephine's Development Overview, (b) Josephine's Motivational Changes

Josephine signed up for Module 3 of STEM@University. She wanted to *“Expand my knowledge of different areas of stem and get a chance to talk to trinity students”*

She spent 2 hours on Assignment 1 and deemed her artefact as being Successful. She gave herself a grade of *“8, as I think I did well but my facts were not very interesting”*.

For Assignment 2 she self-reported spending 1 hour on it. She deemed her artefact as being successful and gave herself an 8.

Josephine’s STEM capital rose slightly from 48.51 to 49.50. On the positive side *“One or both of my parents have explained to me that science is useful for my future”* moved from Disagree to *“Neutral”* and *“My teachers have specifically encouraged me to continue with science subjects after my Junior Cycle”* moved from *“Neutral”* to *“Agree”*. These slightly outweighed the negative shifts in *“One or both of my parents think science is very interesting”* which moved from *“Agree”* to *“Neutral”* and *“It is useful to know about science in my daily life”* moved from *“Strongly Agree”* to *“Agree”*.

Josephine’s self-efficacy sourced from mastery experiences stayed high at 5.83 out of 6, while her self-efficacy sourced from vicarious experiences went from 5.67 to the maximum value of 6. *“Seeing adults do well in science pushes me to do better”* and *“When I see how another student solves a science problem, I can see myself solving the problem in the same way”* all

moved from a 5 to 6. Self-efficacy sourced from social persuasion stayed constant at 5.83 while there was an increase in Josephine's science self-efficacy sourced from physiological states from a 5 to 5.5. There were positive changes in 4 out of the 6 items relating to physiological state, with a negative change in *"I start to feel stressed-out as soon as I begin my science work"*.

Within the SRQ-A, Josephine's RAI decreased from -1.25 to -1.76. She was already extrinsically motivated, and this seems to have shifted in that direction during her time at STEM@University. This is largely due to decreasing amounts of Intrinsic Motivation.

This is exemplified by *"Why do I try to do well in school? - Because I enjoy doing my school work well"* and *"Why do I try to answer hard questions in class? -Because it's fun to answer hard questions"* moving from *"Very True"* to *"Sort of True"*.

Increasing amounts of identified motivation are exemplified by *"Why do I do my homework? - Because it's important to me to do my homework."* moving from *"Sort of True"* to *"Very True"*.

After attending STEM@University Josephine is reporting higher science self-efficacy from two new sources while maintaining her already high self-efficacy in two existing ones. She saw others do science, she did it herself and she feels more comfortable within the subject as a result. Her work could have become more important to her, and this results in an increase in identified regulation.

5.4.12 COA8 – Caoimhe

Caoimhe signed up for Modules 1 and 3 of STEM@University. When she signed up, she said that she wanted *"More knowledge and help in deciding my career."*

For Assignment 2 she self-reported spending 1.5 hours on it. She deemed her artefact as being Successful. She self-scored her artefact as being a *"6, more info would have improved it."*

Caoimhe entered STEM@University already reporting high levels of STEM capital, high amounts of science self-efficacy and had a relative autonomy index that indicated she was intrinsically motivated.



Figure 26 - (a) Caoimhe's Development Overview, (b) Caoimhe's Motivational Changes

Her STEM capital grew from 65.34 to 70.29 during her second module at STEM@University. She moved from having medium amounts of STEM capital to having high amounts of STEM capital. She strongly agreed with the statement *"I know how to use scientific evidence to make an argument"* at the end of the course compared to agreeing with it at the beginning as well reporting that she talks directly with scientists about science.

After participating in STEM@University, Caoimhe is reporting better grades in her texts in school which raises her self-efficacy sourced from mastery experiences. Her vicarious experiences score is raised as *"Seeing adults do well in science pushes me to do better"* and *"Seeing kids do better than me in science pushes me to do better"* and *"When I see how another student solves a science problem, I can see myself solving the problem in the same way"* all moved from a 5 to a 6. Social persuasion rises as *"People have told me that I have a talent for science"* and *"Adults in my family have told me what a good science student I am"* both rise from 5 to 6. The slight decrease in physiological state is accounted for by *"Doing science work takes all of my energy"* moving from a 1 to a 2.

Caoimhe had a good experience at STEM@University. She already possessed high amounts of STEM capital, autonomy, and self-efficacy prior to Module 3, and these all mostly increased during her second course. It is good to see that in this case study, as Caoimhe attended 2 different modules of STEM@University, she was a student who has comparatively high scores compared to her peers.

5.4.13 Summary of Case Studies

In Table 19 and Table 20, a summary of the quantitative changes is given, and sorted based on both pre-existing STEM capital.

Among examination of the tables, no significant effect is noted based on pre-existing STEM capital or relative autonomy index and this is examined in detail. A correlation analysis was done using SPSS between the differences shown in the Tables 18 and 19 above and the pre-existing STEM capital and RAI scores. No significant differences in hypothesised relationships were noted. With the sample of student being so small in this study, it is noted that achieving significant correlations would be difficult. The correlation analysis is detailed in Table 22.

It was aimed to examine all the available data to use to determine these student's STEM identity trajectory. This trajectory has been explained almost as a vector which describes students' identity development at any one time (Jackson & Seiler, 2013). STEM trajectory has also been used within the informal environment (Archer et al., 2021).

When student progression during the experience is examined, it can be seen that STEM identity changes have taken place. These are shown in Table 18 and illustrated in Table 21.

Eibhlín is a student with high levels of STEM capital and a median RAI. She committed large amounts of time on the artefacts and all the reflection sheets compared to her peers. While her STEM capital fell, it remained high, but after completing the programme her RAI grew to the highest recorded score among the students detailed. There were also increases seen among all 4 sources of science self-efficacy.

Caoimhe is a student who completed 2 modules at STEM@University. Upon signing up for Module 3, her high amounts of STEM capital grew even further. Increases were also noted in her RAI and 3 out of 4 sources of science-self-efficacy scale.

Shauna is a median student at STEM@University. She engaged with the artefacts and reflection sheets, spending a reported 2.5 hours on average for every artefact. While her STEM capital and RAI remained constant, her sources of science self-efficacy grew across multiple sources. It would be fair to assume that her STEM identity grew because of participation in the course.

Eoin is a student who entered STEM@University with relatively low amounts of STEM capital compared to his peers on the programme. Given his noted increases across all domains, the author would consider participation on the programme to have increased his STEM identity.

Josephine is a student who had low amounts of STEM capital and autonomy when she entered the course. While her STEM capital and RAI remained relatively constant during her time at STEM@University, there is evidence of her science self-efficacy sourced from her Physiological and Affective states increasing.

Finally, Karen is a student who had relatively low amounts of STEM capital but median amounts of autonomy. Given her development of STEM capital and self-efficacy sourced from vicarious experiences, it can be stated that her STEM identity grew during her time at STEM@University.

When looking at the students whose STEM identity may have decreased throughout their course, their RAI decreased in all instances. The development of Amy, Aoife, Bríd and Teresa's STEM Identity was hampered by their reported decreases within their RAI. When looking at future iterations of this course, taking further steps to improve and support student autonomy could result in better overall student outcomes. This will be discussed in Chapter 6.

STEM Identity Development		
Increase	No Evident Change	Decrease
Josephine	Erica	Amy
Shauna	Daithí	Aoife
Eoin		Bríd
Eibhlín		Teresa
Karen		
Caoimhe		

Table 18 - Student STEM Identity Development at STEM@University

					Pre- Existing		Normalised Differences					
		Module	Number of completed Reflection Sheets	Time Per Sheet (hrs)	STEM C.	RAI	STEM C.	Mas. Exp.	Vic. Exp.	Soc. Per.	Physiol.	RAI
Eibhlín	F	2	3	3.33	1	0.6	-0.17	0.2	0.08	0.17	0.27	0.4
Caoimhe	F	3	1	1.5	0.77	0.81	0.17	0.1	0.23	0.11	-0.09	0.12
Brid	F	2	1	3	0.6	0.56	-0.23	-0.2	-0.08	-0.22	0.09	-0.18
Erica	F	3	0	-	0.57	0.43	0.1	-0.2	-0.23	0.22	-0.09	-0.31
Aoife	F	3	2	1.75	0.53	0.69	-0.3	0.1	-0.54	0	-0.19	-0.48
Daithí	M	2	1	1	0.43	0.14	-0.23	-0.3	0	0.33	0	0.17
Shauna	F	2	2	2.5	0.43	0.51	0	0.2	0.38	-0.11	0.09	-0.01
Karen	F	2	0	-	0.33	0.62	0.2	0	0.16	0	0	-0.04
Eoin	M	2	2	2.75	0.27	0.23	0.27	0	0.46	0.11	0.18	0.11
Josephine	F	3	2	1.5	0.2	0.07	0.03	0	0.15	0	0.27	-0.07
Amy	F	3	1	1	0.03	0.36	0.03	-0.2	0.07	-0.22	-0.27	-0.22
Teresa	F	2	1	2.5	0	0.54	0.03	0.2	-0.46	-0.06	0.09	-0.25

Table 19 - Student Changes during STEM@University sorted by Pre-Existing STEM Capital

					Pre- Existing		Normalised Differences					
		Module	Completed number of Reflection Sheets	Time Per Assignment (hrs)	STEM C.	RAI	STEM C.	Mas. Exp.	Vic. Exp.	Soc. Per.	Physiol.	RAI
Caoimhe	F	3	1	1.5	0.77	0.81	0.17	0.1	0.23	0.11	-0.09	0.12
Aoife	F	3	2	1.75	0.53	0.69	-0.3	0.1	-0.54	0	-0.19	-0.48
Karen	F	2	0	-	0.33	0.62	0.2	0	0.16	0	0	-0.04
Eibhlín	F	2	3	3.33	1	0.6	-0.17	0.2	0.08	0.17	0.27	0.4
Brid	F	2	1	3	0.6	0.56	-0.23	-0.2	-0.08	-0.22	0.09	-0.18
Teresa	F	2	1	2.5	0	0.54	0.03	0.2	-0.46	-0.06	0.09	-0.25
Shauna	F	2	2	2.5	0.43	0.51	0	0.2	0.38	-0.11	0.09	-0.01
Erica	F	3	0	-	0.57	0.43	0.1	-0.2	-0.23	0.22	-0.09	-0.31
Amy	F	3	1	1	0.03	0.36	0.03	-0.2	0.07	-0.22	-0.27	-0.22
Eoin	M	2	2	2.75	0.27	0.23	0.27	0	0.46	0.11	0.18	0.11
Daithí	M	2	1	1	0.43	0.14	-0.23	-0.3	0	0.33	0	0.17
Josephine	F	3	2	1.5	0.2	0.07	0.03	0	0.15	0	0.27	-0.07

Table 20 - Student Changes during STEM@University sorted by Pre-Existing RAI

							Pre-Existing		Normalised Differences					
		Module			Completed number of Reflection Sheets	Time Per Assignment (hrs)	STEM C.	RAI	STEM C.	Mas. Exp.	Vic. Exp.	Soc. Per.	Physiol.	RAI
Change In STEM Identity	Increase	Josephine	F	3	2	1.5	0.2	0.07	0.03	0	0.15	0	0.27	-0.07
		Shauna	F	2	2	2.5	0.43	0.51	0	0.2	0.38	-0.11	0.09	-0.01
		Eoin	M	2	2	2.75	0.27	0.23	0.27	0	0.46	0.11	0.18	0.11
		Eibhlín	F	2	3	3.33	1	0.6	-0.17	0.2	0.08	0.17	0.27	0.4
		Karen	F	2	0	-	0.33	0.62	0.2	0	0.16	0	0	-0.04
		Caoimhe	F	3	1	1.5	0.77	0.81	0.17	0.1	0.23	0.11	-0.09	0.12
		Daithí	M	2	1	1	0.43	0.14	-0.23	-0.3	0	0.33	0	0.17
		Erica	F	3	0	-	0.57	0.43	0.1	-0.2	-0.23	0.22	-0.09	-0.31
	Decrease	Amy	F	3	1	1	0.03	0.36	0.03	-0.2	0.07	-0.22	-0.27	-0.22
		Aoife	F	3	2	1.75	0.53	0.69	-0.3	0.1	-0.54	0	-0.19	-0.48
		Brid	F	2	1	3	0.6	0.56	-0.23	-0.2	-0.08	-0.22	0.09	-0.18
		Teresa	F	2	1	2.5	0	0.54	0.03	0.2	-0.46	-0.06	0.09	-0.25

Table 21 - Student Changes during STEM@University sorted by STEM Identity

			Pre-Existing		Differences					
Pre-Existing			RAI	STEM C	RAI	STEM C.	Mas.	Vic.	Soc.	Phys.
	RAI	Pearson Correlation	1.00	0.49	-0.14	-0.06	0.48	-0.27	-0.21	-0.32
		Sig. (2-tailed)		0.11	0.66	0.84	0.11	0.40	0.52	0.31
	STEM C	Pearson Correlation	0.49	1.00	0.44	-0.33	0.16	0.07	0.40	0.16
		Sig. (2-tailed)	0.11		0.15	0.30	0.63	0.83	0.19	0.62
Differences	RAI	Pearson Correlation	-0.14	0.44	1.00	0.13	0.16	0.67*	0.46	0.57
		Sig. (2-tailed)	0.66	0.15		0.69	0.62	0.02	0.14	0.05
	STEM C	Pearson Correlation	-0.06	-0.33	0.13	1.00	0.14	0.53	0.03	0.05
		Sig. (2-tailed)	0.84	0.30	0.69		0.67	0.08	0.93	0.87
	Mastery	Pearson Correlation	0.48	0.16	0.16	0.14	1.00	0.03	-0.13	0.36
		Sig. (2-tailed)	0.11	0.63	0.62	0.67		0.92	0.69	0.25
	Vicarious	Pearson Correlation	-0.27	0.07	0.67*	0.53	0.03	1.00	0.03	0.36
		Sig. (2-tailed)	0.40	0.83	0.02	0.08	0.92		0.94	0.26
	Social P.	Pearson Correlation	-0.21	0.40	0.46	0.03	-0.13	0.03	1.00	0.16
		Sig. (2-tailed)	0.52	0.19	0.14	0.93	0.69	0.94		0.62
	Phys.	Pearson Correlation	-0.32	0.16	0.57	0.05	0.36	0.36	0.16	1.00
		Sig. (2-tailed)	0.31	0.62	0.05	0.87	0.25	0.26	0.62	
	* Correlation is significant at the 0.05 level (2-tailed).									

Table 22 - Correlation Co-Efficient Matrix

It's hypothesised that there should be some correlation between STEM capital and items on the sources of science-self-efficacy subscale. The link between STEM identity

and self-efficacy has been previously made (Hazari et al., 2010) and the index of science capital instrument was developed to incorporate a student's own self-efficacy (Archer et al., 2015).

A link between motivation and physics identity has been made (Hazari et al., 2010). When this work is put alongside work which links STEM capital with physics aspirations (Archer et al., 2020; Moote et al., 2019) it would indicate that we could look for a correlation between RAI and STEM Capital, however no such link was significantly found in this study.

While a significant correlation was found between a student's RAI differences and their vicarious experiences differences while studying at STEM@University, but to the best of the author's knowledge there is no hypothetical explanation for this.

6 Conclusions and Implications

In this final chapter I will draw down the responses of the study across the various research questions that were posed, outlining the experiences of student participating in STEM@University and what this means for this course and others in the future.

6.1 Research Question 1

1. What were the TY student experiences of the STEM@University programme?
 - a. Did their experience reflect the desired goal of the programme?

The programme's desired aims were to introduce self-selecting students to the STEM college environment. It was hoped that by seeing what college lectures were like, completing age-appropriate tasks and reflecting on their own learning that students would be enabled to study STEM subjects in the future. While this online experience was run by the Trinity Walton Club within the School of Physics, it was designed to not only encourage physics.

The course hoped to achieve these aims by building a student's STEM identity, this will be discussed in more detail in Section 6.2.4. Three specific aspects of student development were targeted to help improve a student's STEM Identity and they are STEM capital, self-efficacy and autonomy, as was discussed in Sections 6.2.1, 6.2.2, and 6.2.3 respectively.

As students were completing the programme, they had choice over large amounts of how they engaged with it. No aspects of the course were mandatory. They had choice of when to view their initial college lecture. The learning environment was one where students could engage with the material as much as they wished, and students reported spending between 0.5 hours to 3.33 hours completing their assignments and creating their digital artefacts. The exam at the end of the programme was optional and accrued no additional benefit for the students.

Qualitatively, we saw that students felt that the course was beneficial. Repeatedly during the focus group, the words (or variations thereof) "*interesting*" and "*enjoy*" were mentioned by all four participants. Content was varied across differing branches of STEM, which students found to be something quite new and different. Students

reported that they enjoyed completing the artefacts and saw new available paths which they could take in their immediate and long-term future that seemed attractive to them.

One way the course could improve would be in facilitating greater autonomy development. While students in the focus group reported that the course developed their autonomy, this is not consistent or corroborated by the quantitative data.

b. What are the recommendations for improving the student experiences?

In accordance with other studies, supports and strategies should be developed for low performing students (Borup et al., 2013; Cavanaugh et al., 2009). While we saw students across the STEM capital and RAI spectrum perform well at STEM@University, it might be possible for instructor check in if students have not completed artefacts or reflection sheets. The selected virtual learning environment (Microsoft Teams) would provide an opportunity for such interactions if desired. Student sometimes welcome support, especially those who are extrinsically motivated (Black & Deci, 2000).

The benefits of reflection and its place within the formal education system have been established in Section 4.8. While students have been prompted with reflection questions in the webinar, it is suggested that given that the benefits of reflection be explicitly taught to students upon taking the course. For reflection to be meaningful, must not seem like pointless add-on work. Students should be aware of its benefits in order to maximise output (Hobbs, 2007).

The programme was designed with choice at the heart of it. Students were given the choice within the module of what their artefact could contain or what it could be about. Students in the focus group noted the independent nature of the course and how the lack of external motivating factors was quite new to them. While choice shouldn't be done for the sake of it, perhaps students could be given a choice of which assignment to complete. However, there is a balance to be cognisant of.

The effect of choice will be optimized by a moderate number of options and choices because too few choices may not allow the perceived effect of choice on feelings of autonomy to be realized, whereas too many choices may lead to ego-depletion. (Patall & Zambrano, 2019)

Furthermore, while the programme isn't a typical classroom environment, it might benefit from adopting more autonomy supportive pedagogy throughout the course elements.

In general, this means asking students what they want, listening to what they say, being responsive to students' input and suggestions, and appreciating the engagement-fostering potency of students' interests, goals, and personal strivings. (Reeve & Shin, 2020)

For the educators within the programme, they should provide reasoning for artefacts and reflections, recognise negative emotions that may exist with regards to completion of course elements and use invitational language with students (Reeve & Shin, 2020).

6.2 Research Question 2

2. Does the STEM@University programme develop TY students?
 - a. STEM Capital
 - b. Self-Efficacy
 - c. Autonomy
 - d. STEM Identity

6.2.1 (a) STEM Capital

Matching the data from the quantitative instrument to the focus group is interesting. The intake of students into the programme was what would be expected from a programme like this. This wasn't a STEM capital intervention for those with low amounts of STEM capital, but instead was an experience where those who signed up had high amounts of STEM capital.

In this group, STEM capital increased in 7 out of the 12 case studies and 1 student moved from having medium amounts of STEM capital to high amounts of STEM capital. This could be evidence of students' STEM identity growth. As noted, when the focus group data was being specifically discussed, it is hard to make conclusions based on the small and self-selecting sample, but within the focus group it can be seen that there is evidence of student attitude change and evidence of course feature design coming through to the students. Also from the focus group is evidence of people who may not

consider themselves to be a “*science person*” maybe coming around to the idea after participation in the programme.

Responses in the index of science capital instrument to questions such as “*A science qualification can help you get many different types of job*” can be tied to data from the focus groups, where students report seeing third level courses, students, jobs, and careers in a new light. Agreement between the quantitative and qualitative data from this study matches that conducted within the ASPIRES group. They previously have reported that students will make decisions on subject choice based on their chosen career or academic path primarily. There was evidence of subject choice change within the Focus Group. This marriage of short and long term changes of interests matches the qualitative data presented within this study (DeWitt et al., 2018).

6.2.2 (b) Self-Efficacy

As noted previously in Section 5.2, when this group of students were compared to other comparatively similar samples of students, high amounts of science self-efficacy from many different sources was seen in the results from the sources of science self-efficacy instrument and re-affirmed by data from the focus group.

During the course, non-significant increases in self-efficacy sourced from vicarious experiences, social persuasion, and physiological states, along with a non-significant decrease in mastery experiences were noted by the students.

Within the focus group, students reported changes in their vicarious experiences because of seeing other students and their artefacts, and this matches the data which was seen in the quantitative instrument.

“Then creativity as well, I found that the artefacts that they asked you do weren’t that specific. So you really got to take your own interpretation and everyone’s project kinda looked different.” – Niamh.

“You never really see people doing Masters or PhDs. It’s not something that teachers will tell you when they are asking what you want to do, “Do you want to go into research in the subject?”. And then see in the Disappearance of a

Massive Star, they were studying and showed the interesting things that you can do for a PhD” – Daniela.

There were increases in social persuasion in the quantitative instrument, but no direct evidence of this was coded within the focus group.

There was an increase in science self-efficacy sourced from physiological state in both the focus group and the sources of science self-efficacy scale. It is interesting to note that within the focus group, even students who demonstrated high amounts of science self-efficacy spoke about the intimidation of STEM that they experience before commencing the STEM@University programme. Tying these two together, it can be inferred that participating in the STEM@University course saw students own fears quenched as they conducted independent research, completed artefacts, and spoke with people who were actively working within the field of STEM. Assuming the role of a scientist, seeing other scientists and seeing that they were like other students who wanted to be scientists can reduce science related anxieties and fears.

Repeating this study with a bigger sample of student would be insightful and address some emerging questions. Could participation in such a study increase science self-efficacy among those students in the lower self-efficacy groups. Would it be possible to see a significant level of increase in the sources of science self-efficacy among a larger sample of students?

6.2.3 (c) Autonomy

As detailed in Section 3.4.5, the students entering STEM@University demonstrated comparatively high amounts of autonomy compared to their peers both nationally and internationally according to their RAI. While the course intended to increase student autonomy, the students who self-selected to participate within this study already were more autonomous than their peers. It’s also noted that students who were deemed to be more autonomously motivated were the students who completed both the pre- and post-questionnaires.

Findings from the SRQ-A showed slight decreases in identified regulation, introjected regulation, and intrinsic motivation with an increase in extrinsic regulation within the

matched samples. As noted earlier when discussing the findings from the data, some of these changes could be outside of the control of STEM@University.

While the data from the SRQ-A shows a non-significant decrease in RAI, this is at odds with the data from the focus group. Students within the focus group reported increasing amounts of what was coded as identified regulation, with multiple aspects of what was coded as intrinsic motivation as well as perceiving features of the programme which were intended to increase student autonomy. These findings disagree with previous studies on the topic where students feel more autonomously supported and also increase in their autonomous motivation as measured by changes in their RAI (Black & Deci, 2000; Kroes, 2021). These students sampled did have high amounts of autonomous motivation before commencing the course and the lack of effects of autonomy supports on students who have competitively high amounts of autonomous motivation have been noticed previously (Black & Deci, 2000). By signing up to this course and participating in the study, the students that they are autonomously motivated, perhaps widening the scope of sampling would allow more insight into this.

It should be noted that a total of 119 students representing 38% of the course were motivated enough to take a completely optional exam for no external benefit. This indicates that there is more to be investigated here with regards to autonomy acquisition.

6.2.4 (d) STEM Identity

Identity development has been described as a motion either towards or away from Science (Jackson & Seiler, 2013). Answering this research question involves taking all available qualitative and quantitative data into account and determining the overall trajectory of development. Case studies were prepared to portray a holistic view of each individual's experience to determine their STEM trajectory similar to other work as detailed in Section 5.4.13. It is felt that there was development in the STEM identities within 6 of the 12 case studies examined during this programme.

During the course, most students reported increases in STEM capital and self-efficacy sourced from social persuasion, vicarious experiences, and their physiological state. This quantitative data matches what was seen in the focus groups, where students reported

seeing STEM in a new light and feeling more comfortable within the STEM world after participation in the programme.

This aligns with statements where within early childhood education informal learning can be used to leverage conversations with significant others (Dou et al., 2019). Even though Transition Year isn't within early childhood education, it is a significant time of decision making for teenagers and it is natural that students would turn to their parents for advice.

While there are no significant increases observed amongst this data, it would be highly beneficial to perform this study again with higher amounts of student data

Students who participated in the focus group felt the course offered ample opportunity for them to develop their STEM skills and see what a life in STEM could be like. It must be noted again that the focus group was an opt in process and highly unlikely that aggrieved students would be willing to join this group and share their negative experiences. For the subset of students who did part take in the focus group, the findings were very positive, and students openly discussed how they saw themselves within STEM, how they felt more comfortable within the world of STEM and actions that they wished to take as a result with regards to their Senior Cycle subjects as a result of taking this course.

6.3 Implications

This research has allowed me to evaluate the experiences of transition year students from a non-formal STEM learning programme, STEM@University, and identify recommendations for making changes to the programme design and areas for further research.

6.3.1 STEM@University Programme

Examining changes that could be made to the elements of STEM@University should be done within the existing desired aim of the programme; that developing student STEM identity is important. A review of the existing STEM education frameworks identified features that should be utilised to design an effective STEM curriculum (Butler et al., 2020).

As this course strives to improve, looking towards the ATS Conceptual Framework for further gains could be done. It can be said though that this programme does already integrate large aspects of this framework and further integration of desired outcomes of STEM curricula would see further STEM identity development.

The course may find it difficult to facilitate some aspects of this framework within their own, but structured module syllabi which are designed to integrate specific aspects could be done. For example, the Medical Devices lecture and artefact in Module 2 was one which integrated *Engineering Design and Practices* into that module. It should be possible to enable this throughout every module.



Figure 27 - Expanded ATS STEM Conceptual Framework for Integrated STEM Education (Butler et al., 2020).

As discussed in Section 2.1.2, STEM capital is fast becoming a social justice issue and as a course it is felt by the author that it is one cannot be ignored. The availability of scholarships to begin to address any imbalances, whether it might be gender, racial or social, within the course could be implemented. As students' participation isn't one that depends on physical space within a lecture hall or classroom, this environment can be leveraged to facilitate STEM Identity development among disadvantaged groups. Development of STEM identity was largely independent of pre-existing STEM capital, and this could be utilised to development within under-represented groups.

6.3.2 Further Research

This research was hampered by recruitment of participants, conducting this experiment again but with a cleaner and easier sign-up process could yield increased amounts of participants, increasing the amount of data that could be obtained in both the quantitative and qualitative aspects of data collection.

Evaluation of the quantitative instruments has been interesting. The index of science capital instrument worked well and further refinements would be to obtain and compare this data alongside the previously obtain population wide data using the same instrument (Archer et al., 2015; Moote et al., 2019). This would allow us to compare this population sample and more accurately define who had low, medium, and high amounts of STEM capital. Not only that but using the index of science capital Instrument outside of this environment would be interesting, the author would like to see what the results of a population wide study in Ireland would obtain. I would particularly be interested in examining this from a gender perspective given that I currently teach in a school which is for girls.

The SRQ-A instrument had many questions which related to school, teachers, and classwork. This instrument could be substituted with the modified version of the academic motivation scale – high school version (Vallerand et al., 1989), where school is replaced with STEM@University. This would require validation and examination of the items involved but also could lead towards a dedicated instrument for motivation in non-formal education settings. Finally, a direct measure of self-efficacy to sit alongside the sources of science self-efficacy instrument would not only validate the findings within the latter instrument but also give us more insight into how students were processing the course.

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8 Appendices

8.1 Index of Science Capital

(Archer et al., 2015; Moote et al., 2019, 2020)

Item	Response Options
A science qualification can help you get many different types of job.	–2 for strongly disagree, –1 for disagree, 0 for neither, 1 for agree, and 2 for strongly agree
When you are NOT in school, how often do you talk about science with other people?	–2 for never, –1 at least once a year, 0 at least once a term, 1 at least once a month, and 2 at least once a week
One or both of my parents think science is very interesting.	–1 for strongly disagree, –0.5 for disagree, 0 for neither, 0.5 for agree, and 1 for strongly agree
One or both of my parents have explained to me that science is useful for my future.	–1 for strongly disagree, –0.5 for disagree, 0 for neither, 0.5 for agree, and 1 for strongly agree
I know how to use scientific evidence to make an argument.	–2 for strongly disagree, –1 for disagree, 0 for neither, 1 for agree, and 2 for strongly agree
When not in school, how often do you read books or magazines about science?	–2 for never, –1 at least once a year, 0 at least once a term, 1 at least once a month, and 2 at least once a week

When not in school, how often do you go to a science centre, science museum, or planetarium?	-2 for never, -1 at least once a year, 0 at least once a term, 1 at least once a month, and 2 at least once a week
When not in school, how often do you visit a zoo or aquarium?	-2 for never, -1 at least once a year, 0 at least once a term, 1 at least once a month, 2 at least once a week
How often do you go to after school science club?	-2 for never, -1 at least once a year, 0 at least once a term, 1 at least once a month, and 2 at least once a week
My teachers have specifically encouraged me to continue with science after Junior Cycle	-2 for strongly disagree, -1 for disagree, 0 for neither, 1 for agree, and 2 for strongly agree
My teachers have explained to me science is useful for my future.	-2 for strongly disagree, -1 for disagree, 0 for neither, 1 for agree, and 2 for strongly agree
It is useful to know about science in my daily life.	-1 for strongly disagree, -0.5 for disagree, 0 for neither, 0.5 for agree, and 1 for strongly agree
Who do you talk to about science? Who are they?	0.5 for parents or carers, 0.5 for extended family, 0.5 for friends, 0.5 for siblings, 0.5 for directly with scientists, 0.5 for teachers, 0.5 for other, and 0 for no one
Do you know anyone who works in science? Who are they?	2 for parents or carers, 1 for siblings, 1 for extended family members, and 1 for other

8.2 Sources of Science Self-Efficacy Scale

(Britner and Pajares 2006, Usher and Pajares, 2009)

1. I make excellent grades on science tests
2. I have always been successful with science
3. Even when I study very hard, I do poorly in science
4. I got good grades in science on my last report card
5. I do well on science assignments
6. I do well on even the most difficult science assignments
7. Seeing adults do well in science pushes me to do better
8. When I see how my science teacher solves a problem, I can picture myself solving the problem in the same way
9. Seeing kids do better than science in science pushes me to do better
10. When I see how another student solves a science problem, I can see myself solving the problem in the same way
11. I imagine myself working through challenging science problems successfully
12. I compete with myself in science
13. My science teachers have told that I am good at learning science
14. People have told me that I have a talent for science
15. Adults in my family have told me what a good science student I am
16. I have been praised for my ability in science
17. Other students have told me that I'm good at learning science
18. My classmates like to work with me in science because they think I'm good at it
19. Just being in science class makes feel stressed and nervous
20. Doing science work takes all of my energy
21. I start to feel stressed-out as soon as I begin my science work
22. My mind goes blank and I am unable to think clearly when doing science work
23. I get depressed when I think about learning science
24. My whole body becomes tense when I have to do science

8.3 Academic Self-Regulated Questionnaire

(Connell & Ryan, 1989)

A. Why do I do my homework?

1. Because I want the teacher to think I'm a good student.
2. Because I'll get in trouble if I don't.
3. Because it's fun.
4. Because I will feel bad about myself if I don't do it.
5. Because I want to understand the subject.
6. Because that's what I'm supposed to do.
7. Because I enjoy doing my homework.
8. Because it's important to me to do my homework.

B. Why do I work on my classwork?

9. So that the teacher won't yell at me.
10. Because I want the teacher to think I'm a good student.
11. Because I want to learn new things.
12. Because I'll be ashamed of myself if it didn't get done.
13. Because it's fun.
14. Because that's the rule.
15. Because I enjoy doing my classwork.
16. Because it's important to me to work on my classwork.

C. Why do I try to answer hard questions in class?

17. Because I want the other students to think I'm smart.
18. Because I feel ashamed of myself when I don't try.
19. Because I enjoy answering hard questions.
20. Because that's what I'm supposed to do.
21. To find out if I'm right or wrong.
22. Because it's fun to answer hard questions.
23. Because it's important to me to try to answer hard questions in class.
24. Because I want the teacher to say nice things about me.

D. Why do I try to do well in school?

25. Because that's what I'm supposed to do.
26. So my teachers will think I'm a good student
27. Because I enjoy doing my school work well.
28. Because I will get in trouble if I don't do well.

- 29. Because I'll feel really bad about myself if I don't do well.
- 30. Because it's important to me to try to do well in school.
- 31. Because I will feel really proud of myself if I do well.
- 32. Because I might get a reward if I do well.

E. Why do I sign up for extra-curricular educational activities (like STEM@University)?

- 33. Because it's fun
- 34. Because I enjoy a challenge
- 35. Because I want others to think I am smart
- 36. So my teachers will think I am a good student
- 37. Because I will feel really proud of myself
- 38. Because I want to learn and experience new things
- 39. Because I want to see what college is like
- 40. Because I want to prepare myself for third level education
- 41. Because my parents want me to do it

8.4 Focus Group Transcript

Lucy - "It was really interesting as we got to see three different areas of STEM which is different from other programmes that I've done in the past. There was maths and Engineering, there was also science and the marine biology aspect of it so I found that really interesting and I also learned a lot about(inaudible) so I found that really interesting"

(How did you find it?)

Edward - "I found it really good, really interesting. It was different from what you do in school. I'm not doing physics for the Leaving Cert but even going through the last 2 seminars, they were really interesting. It's something that you could experiment with in college. It just sorta broadened my horizons not to be cringey but..."

(Introduce Yourself)

Lucy - "I wasn't originally going to sign up for the course in Trinity at all because I was going to do it for the first module, but I was already going to be doing an

engineering course in DCU and I thought it might be a bit too much focus in that area. I was like, I should be exploring other fields, but then I signed up for the second module, and really enjoyed it. physics is going to be one of the subjects I pick for the Leaving Cert, along with chemistry and the other sciency subjects, that's kinda like the area I am interested in. That's kind of it."

Edward - "I wanted to do this course as both my brother and sister went to Trinity and I wanted to see what it was like. We didn't do a lot of physics for the Junior Cert, but I liked math. They're similar in ways, it's kinda applied math with theory so I enjoyed it in that respect. But I think if I could go back and do my subjects out, I'd think about doing physics more."

Niamh - "I also did the course as both my brother and sister both went to Trinity and I wanted to see what it was like. I was also really confused whether I wanted to go into STEM or wanted to go into arts cause I've always liked English but I also really like science as well. I thought that doing the course would give me a taste of what it would be like in college, because you don't really get to do much science in Junior Cert. So, I wanted to see what it was like, and I really enjoyed it! So that's why I ended up choosing STEM courses for the Leaving Cert, so I could possibly end up doing it in college."

Daniela - "I just did cause I really like Science, I chose Biology and Physics for the Leaving Cert and I wanna do Theoretical Physics in college, so I just really like Science."

(Can you tell me about your time at STEM@Uni)

Daniela - "I really enjoyed the first one, I found it really interesting, the one about space and cause I really enjoy that kind of thing. All the lectures were really interesting and the assignments were like fun, because they weren't like work. They were things that you had to research and do fun presentations about".

Niamh - "I really liked The Physics of Sport one, that's the one I enjoyed the most especially the ice-skating one, that really caught my eye that whole course because I'm interested in sports and really made me wanna pay attention and do other research as

well because I was just so interested in it. It's probably the reason why I'm going to do Physics for the Leaving Cert."

Edward - "My favourite one we did was the second one, the Paleontology one. We were chatting about the Earth's different climate systems and the dinosaurs, and its transition states throughout the eons. I suppose I really liked dinosaurs as a kid and I sorta enjoyed that throwback aspect of it. I think that was like my favourite, but apart from that I think The Disappearance of a Massive Star was really cool. I really liked space as a kid too I thought it was really nice to go back to that."

Lucy - "I really enjoyed all three, the puffins, the needle and the stress and strain and the marine biology, all three of them were really interesting. If I had to pick a favourite one I think I'd pick the stress and strain one was really interesting because I really liked doing the artefact for that one, creating your own problem and see who was at fault it was, that was really interesting for me. I wanted to do the exam as well, but I just missed the messages and I didn't realise there was a start and an end time messages so like I missed it because of that. Other than that I'd say it was really ...good. I wouldn't say that it influenced my decision to do physics as a whole because I feel that there were other aspects, but it did really help me to see that is like other aspects to STEM, instead of it being "Oh computer science, Oh physics, stuff like that". It really does include stuff like science technology engineering and mathematics, all four of them. I really enjoyed it. It was a very diverse experience. "

(What do you feel developed, if anything, over your time at STEM@University)

Edward – "I feel more grounded, and knowledgeable about Earth itself. The operations that are going on around us that we don't really take in on a day to day process. At the same time from that, you develop a lot more critical thinking skills, that if one star dies another star will form out of that. So you need to know that the step by step process until it becomes engrained into your brain. You start to become more mature and serious, and driven about what you want to do. For someone who was unsure about STEM, and they did this course and is now coming out the other side of it that they would be a lot more mature and a lot more serious, and a lot more grounded again in that this is what they wanted to do. And would have given them the push."

Lucy - "Some of the skills that I put down are like, doing up the artefacts. Two of my artefacts were that you had to present research or create your own thing. So that skill of report writing, I had never done a scientific report before properly before we were given the artefact about Buffon's needle and the different ways of finding Pi. So that for me was a skill that I found I learned, writing up a scientific report, because that I will use that in the future. It was good for me to get a taste of it in TY. I don't know how to put this in a skill but kinda, Ownership of Learning, because we were sent the lectures every Tuesday and it was up to us to finish them and understand them, or we have our live classes on the Thursday so that like sense of "You need to get it finished, and if you don't understand one section well you go off and you do your own research and try and understand it as best you can", because you can't just ask a professor. Well you could have, but that initiative, ownership of learning, to just go and research that thing that you found difficult by yourself, to learn it by yourself. That was a skill I learned throughout the course.

Daniela - "Obviously I learned about the topics that were covered and then research skills for the artefact. You had to do your own research, googling things, and finding reliable sources. And then, presentations and PowerPoint skills from the artefact and doing it up yourself."

Niamh - "I would say a broader understanding of the different aspects of STEM and what it will involve in college. I definitely agree with Lucy in the sense that I definitely got better at working independently which will be really useful. You know they gave you the lectures, you had to do them, otherwise you weren't going to understand the live lesson and you were working with your own initiative which will be really useful when it comes to college. Then creativity as well, I found that the artefacts that they asked you do weren't that specific. So you really got to take your own interpretation and everyone's project kinda looked different. And also the variety in physics, I learned about. I wasn't that interested in physics at the beginning, I thought it was just math. I just thought it was what I was learning in Math mixed in with what I was doing in science. But because all the sections of the module were really different, it was just really fun to see what they would be like"

(Did anything else from the others resonate with you)

Edward - "Working independently. I think that is a really tough skill so I would put a high value on that. That's a really transferable skill, it's not just useful in STEM but in every aspect of life and anything you want to do going forward."

Lucy - "The one that Niamh said, you know learning about the deeper aspects of STEM. Realising that physics isn't just one thing, it's like deeper. For me, it was that STEM isn't just about maths and engineering. It's not just that. When they say science, technology, they do mean all the sciences, like biology, chemistry and physics. I didn't realise that before. I would put a high value on that as it expanded my general knowledge of STEM."

Daniela - "My organisation and self-directed learning... learning yourself"

Niamh - "What Daniela said about ICT skills, the PowerPoints and stuff. That definitely resonated with me. It's important for me to learn how use that stuff as it something that I will definitely use in college."

(Ranking them)

(Justify #1, Ownership of Learning)

Niamh - "I found that my school experience was not that independent in secondary school. You were given your work and you did your work, and it was all kinda very similar to everyone within the class. So, when I would hear about my brother and sister who were in college talking about their workload and how independent it was, how there wasn't much contact time apart from with tutors, I found that really intimidating as a concept. So to do a course like this, where I actually enjoyed being independent, working independent, and I just think it was really important for me to figure out that it was not that scary and it was actually enjoyable and it does work with a lot of people. And to also figure how on my own, how I would manage the workload myself to be independent in an effective way. So that's why I think it's the most important because it will apply to life forever."

(How was it independent?)

Niamh - "I suppose like you have to go to school, like my parents make me go to school every morning. The zoom classes that I had during quarantine were like, you had to be there, because they were taking attendance. But going to the online classes, the streamed ones and the lectures, no one was taking attendance, no one was going to care if you weren't there. You had to take it upon yourself to take an interest and go to the thing. Also, my parents were going to make me go, and would be disappointed if I didn't, but it was also even just listening during the classes. It would have been easy for me just to shut the door and not listen throughout. But I had to take it upon myself to listen, to take part, there was nobody looking over my shoulder throughout the whole thing.

(Ranking them)

(Justify #1, Ownership of Learning)

Daniela - "How is so different to school, like basically the same as Niamh, if you didn't watch the lectures, like there was nobody there to tell you that you had to watch them. The artefact as well, if you didn't do it, they wouldn't like scold you or anything like that. You just took it upon yourself to do it, it was very different to secondary school."

(Ranking them)

(Justify #1, Ownership of Learning)

Edward - "Similar to Niamh and Daniela, you weren't going to get reprimanded if you didn't do it, no one was going to send a letter home or ring home or anything like that. You were there because you wanted to be there and you wanted to work to find out more. That in itself kinda brings out a higher quality of work because you know that if you are interested in it that you can provide the next step. You know, if you're in school and you're in a Geography class and you don't like Geography, you're not going to give that what you fully can. You're just going to do it to get it fully done, compared to here, where you wanna do it and you wanna do it well because you find it interesting and you wanna prove to yourself that you can do it well. Sorta like that."

(Justify Report Writing)

Lucy - "For me I listened to the others talking about ownership of learning and independence was their number 1, the reason I put it number 3 and report writing is number 1 is, Ownership of Learning, I experienced that for the first time when we had to study for the Junior Cert during quarantine. In our school the teachers gave us the work that they wanted us to get done. There wasn't any pressure, they just told us that it would be good if you could get these things done and that was something that I enjoyed, that ownership of learning. Because it meant that I could do it whenever I wanted to do because I had the work all in bulk, so it was up to me to structure to get it done when I wanted to get it done there. In the STEM course it was the exact same and I really enjoy that style of learning, where you get to decide when you finish the lectures and it's upon to yourself to do it. In terms of that it was good.

But report writing was my number 1 because I said before that I've never really done like a proper report, I mean we have done essays and research papers in school but we haven't really done a scientific report. For me, that experience was really good to have especially if I want to go into a STEM course in the future. Because it's better for me to get an experience of it now, than to be trying to struggle with it in college when it means more than it did in this programme. It was an invaluable skill that I did learn and that stood and will stick with me."

(Did participating in the programme make you more or less comfortable with STEM?)

Niamh - "It definitely made me more comfortable as I knew already about the different aspects of STEM, like I talked about earlier. The scariest thing about STEM was that I didn't know much about STEM. I only had the surface knowledge of engineering, physics and biology, I didn't have any idea as to what was really different about them, or why I would do one over the other. So, to get a basic knowledge as to what they will involve in college, why I should do them, which parts I like which parts I don't like, like for example I really did enjoy The Physics of Sport one, and even though I did enjoy the Disappearance of a Massive Star it wasn't my favourite. It was good to figure out which

parts of STEM really excited me and made me want to do it for my Leaving Cert and maybe in college.”

Edward - “I think it did. Compared to other people in my school who wouldn’t have done this course, they’ve just like the national curriculum level version.”

Lucy - “I think it defiantly did make me more comfortable because it helped me realise that there are so many different aspects in the huge field of STEM so that you can go into. Like it’s not really limited to just the one topic of like engineering or maths. For me it defiantly increased my level of comfort in STEM. For all 3 of my modules, one of them was from science and 2 were from the maths/physics side of things. I think it was a good mix. I’m listening to the others talking about their modules and they also seem really interesting and I really would’ve enjoyed those. But that’s the thing, I didn’t even know that things like Palaeontology would be covered and like it really shows the diversity of the field itself.”

Daniela - “Definitely more comfortable, but I’ve kinda always really had an interest in Science. I knew that I liked it and everything. I kinda just liked learning new things within each individual module.”

Edward - “It definitely did. People in my year group around the country who didn’t do this sort of programme or anything like it, they would just know the bare minimum of what the curriculum provides. The curriculum doesn’t do an overview of massive stars, palaeontology, or stress release. It sorta goes into different avenues that you can really expect from someone doing like a masters in something like that. Being taught by masters students who know what they want, you’re getting good quality teachers. In that way I think it’s better for you to do these things. It does make you more comfortable and it does break you into the world of STEM which can be quite intimidating sometimes.”

(Why is STEM intimidating)

Edward - “It’s sort of seen that you have to be of a certain IQ level to be into STEM, that you’re really smart or you’re really mathsy or something. When STEM has so many different branches, it’s not just like maths, it’s biology, it’s chemistry, it’s social sciences,

it's everything combined into it. It's not your traditional maths and physics. I think that if people knew they'd be more open to it in the end up.

(Did STEM@Uni take intimidation out of it)

Daniela - "Definitely, like I've never found the STEM subjects hard or anything, but it definitely showed what university STEM is like, that it isn't incredibly complex topics that it's things that are part of your everyday life that you can see."

Niamh - "I definitely agree (with what they said), getting a wider knowledge of STEM and it being intimidating. For example, like I wasn't that great at maths at the beginning of secondary school. I really enjoy math now but it was definitely the subject where I was "Well I like English so I don't really like math", like in my head they were polar opposites. But the idea of STEM being more than just about maths, like especially Physics, is something I just really ruled out from a really young age because I decided I wasn't good at math. I just think it's really good to do a course like this because in secondary school the subjects are so segmented, and they never really interact with each other. So that have subjects interact that takes away the whole intimidation aspect to STEM cause it links into so many different aspects.

Lucy - "I definitely agree with Daniela and Edward a lot in terms that I've seen the intimidation that some of my classmates that haven't had an experience of this course who wouldn't go towards STEM at all. Just because they have seen it at school and the way that some of our science teachers teach the course is in a way that is not that thought provoking like showing science as this aspect of creativity, it's more showing science as a thing that you need to memorise. A lot of students just think of science as something boring and they just completely steer themselves away from it, towards the arts or business whereas I feel that if the science course in our schools was taught the same way that it was taught in the STEM programme that we did here, I feel like a lot of students would realise that science has a lot more creativity in it, that it's not just memorisation. I think there is an intimidation that needs to go away and I feel that it could be done if Science was taught not like in a way in the (national) programme."

(How did STEM@University foster that creativity?)

Lucy - "I just feel that the way it is taught in schools, is that it's like you open your book and there's the chapter and your teacher starts reading. And then they go, you need to know this this this for the test, and like that's it. Whereas in the programme there's like this much theory and then the rest is like explaining how it's used and it's application in everyday life. The artefacts also explore that thing, they weren't just recite what you've learned from the lecture word by word. It was like a report, it was go off and do your own research, based on what you've learned in the lectures. In that sense, that's how the lectures and school differed. It's a type of teaching that some science teachers do give, like they do show science from that creative perspective. It's what helped me definitely, to help me lean towards physics. My physics teacher, he taught it in such a way that it is creativity oriented. Most teachers I've seen they don't teach it in such a way and that's where you lose students who say "Oh I'm not good at maths, and it looks really boring so I'm just going to completely forsake it". The programme did a really good job of showing that creative aspect that many teachers fail to show as they are too busy just trying to finish the course or whatever"

(Can you see yourself doing anything different in near future)

Daniela - "I always knew that I wanted to do STEM, this has really solidified the fact. It's something that I really I want to do, it's something that I find interesting. I'm doing all sciences for the Leaving Cert... I definitely will look up more stuff in physics over the summer, more stuff that I find interesting myself."

Niamh - "In regards to picking my subjects for the Leaving, that would be a big one. I didn't really want to pick physics cause I didn't know much about it and the only knowledge I had was that it was like math, just doing math more times a week wasn't that enticing to me. But this course showed me that it can be really exciting and it applies to practical aspects. It's taking math but it also how maths works by walking or running or competition. It really made me think more about it and choose it for the Leaving Cert as I got a bit more excited about it from doing the course."

Edward - "I think I'll end up actually studying STEM subjects whenever I do go to university, I'm studying physics, chemistry and biology for the Leaving Cert. I think I'm

gonna put a lot of emphasis on those when I go into 5th year and knuckle down into a lot of work as I know it's what I want to do in the long term"

Lucy - "To be honest not really, just because my interest in physics and all came a little before the STEM course. Because of the course I'd done before in different places. The main thing it did change was me realising how many different aspects to STEM there were. That's the only change to me that would happen in the immediate future, that I would be more open to such a vast field."

(Can you see yourself doing anything different in distant future)

Lucy - "Maybe I mean I don't know, 5 years in the future is such a long time... one thing that the course has showed me is that just because you choose a discipline in college it doesn't mean that you are restricted to that because that one discipline will intersect with so many of the other of the different disciplines so you will get to work with so many other departments and subjects all the time. That's one thing the course has made me realise, let's say I go into a specific field and I don't really like it, I'll still have the exposure to the other aspects of STEM so if I wanted to change it wouldn't be that difficult. You're always interacting with the material because you're working with different departments, that would be the main change it would make in the distant future"

Daniela - "I already was interested in STEM but it definitely solidified the fact that I want to go into further research after undergrad. Seeing Masters and PhD students who were teaching, really solidified that is that I want to do after my degree, to do a PhD."

"You never really see people doing Masters or PhDs. It's not something that teachers will tell you when they are asking what you want to do, "Do you want to go into research in the subject?". And then see in the Disappearance of a Massive Star, they were studying and showed the interesting things that you can do for a PhD."

Niamh - "For me it would be picking my degree because before the course I was like I'm definitely doing economics or politics or something but doing the course has definitely widened my horizons. Now I feel that I can maybe a STEM course in college,

it would be definitely something that'd be considering as well as doing further research as time goes on to figure out what I want to do"

"We were talking about creativity earlier, I didn't see creativity as a massive thing in STEM, I thought that being creative was coming up with ideas for essays and looking and reading books, and sort of just fiction or even non-fiction like politics. But through the course, doing something like The Physics of Sport or The Disappearance of a Massive Star, where it was about things that you wouldn't really be taught in a science class. Like I was seeing Masters and PhD students saying that they were studying this in university, so, even just from seeing them doing something that I would be genuinely interested in. And then realising that that was STEM was really helpful for me"

Edward - "Sort of similar to what Niamh and Daniela said there, I'd love to do a Masters in any form of STEM, and I'd love to actually go on and become a lecturer in it. I think that would be really cool. With being a lecturer you're doing active research so you're constantly in the know, so you're not just being a textbook verbatim. You're constantly in the flow of whatever the chosen discipline or community you are in."

(Is there anything else you would like to add)

Edward - "I sorta like the way at the end that our scores weren't publicised, I feel that also would have been the way there if we were on campus, there wouldn't have been an air of competition. I just felt that everyone would have been comfortable, the lecturers were comfortable with the students and the students were comfortable with the lecturers. I was a nice environment to learn and I felt that was very effective."

Niamh - "I did other online courses and there wasn't much independent work, like the artefact. It allowed me, and encouraged me to do further research on the topic, to be more creative about it in my own interpretation. I really liked the artefacts, they were fun. "

Daniela - "I found the artefacts to be something different, like a creative spin on what you were doing. Like there was one, attracting an alien to come to earth. That was a really fun way of learning more. All the topics that we covered in the lectures were

really interesting, I really loved learning about them cause they were all interesting topics and they were done was really interesting.”

8.5 Note Taking Sheet

STEM@Universi-TY

provided by Trinity Walton Club

Seminar: Physics by Powers of 10

Lecturer: Dr Eric Finch

Course: Physics

School: Physics Faculty of STEM

Vocabulary

Make a note of any new-to-you vocabulary, or words used by the lecturer you are unsure of. These will be addressed in this week's seminar.

Word	What I think it means	Definition provided

General Notes and Questions

Power of 10	Topic	Notes or Questions you have
25		
24		
23		
22		
21		
20		
19		

18		
17		
16		
15		
14		
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2		
11		
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-1		
-2		
-3		
-4		
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-6		
-7		

-8		
-9		
-10		
-11		
-12		
-13		
-14		
-15		

8.6 Artefact Description

Buffon's Needle

Artefact

1. Find 3 *original* other ways of estimating π .
2. Use one (or an easier one) to estimate π yourself at home.
3. Reflect on sources of error on your estimation of π .
4. Sum up everything in a scientific report.

Buffon's Needle

Scientific Report

1. **Introduction:** Why am I doing this? Methods for estimating π .
2. **Experimental Methods:** Details of the experiment used to estimate π .
3. **Results:** The value of π measured.
4. **Discussion:** How does my result compare to the real value? What are the sources of error?

Figure 28 - Outline of Desired Student Artefact

Buffon's Needle / Pi Artefact Assessment

1. What best describes your gender?

- ☐ Male
- ☐ Female
- ☐ Prefer Not To Say
- ☐ Prefer Not To Self Describe

2. Please Describe Your Gender Identification Here

3. Are you participating in the research study?

- ☐ Yes
- ☐ No

Unique Identification Code (UIC)

This UIC should be the same code that you used previously.

4. First letter of mother's first name?

5. Number of older brothers (if none, put 0)?

6. First letter of middle name (if none, use X)

7. Number representing the month you were born? (January = 01, February = 02, etc.)

8. What best describes your gender?

- ☐ Male
- ☐ Female
- ☐ Prefer Not To Say
- ☐ Prefer Not To Self Describe

9. Please Describe Your Gender Identification Here

10. How much time (in hours) did you spend on your artefact this week?

The value must be a number

11. Next lecture, how much time do you plan to spend creating your artefact?

- ☐ significantly more time
- ☐ a bit more time
- ☐ about the same amount of time
- ☐ a bit less time
- ☐ significantly less time

12. Does the type of artefact requested impact your answer above?

- ☐ Yes
- ☐ No

13. What kind of assignment would encourage you to spend the most time on your second digital artefact?

14. Overall, how do you think you performed on this week's artefact?

- ☐ Exemplary
- ☐ Successful
- ☐ Average
- ☐ Below Standard
- ☐ I did not complete this week's artefact

15. Did you do any of the following?

	Yes	No
Find at least one way to estimate pi	☐	☐
Find at least two ways to estimate pi	☐	☐
Find at least three ways to estimate pi	☐	☐
Find MORE than three ways to estimate pi	☐	☐
Estimate pi yourself	☐	☐
Write a scientific report	☐	☐
Create a meaningful title	☐	☐
Write an introduction	☐	☐
Write an introduction that explained why you want to calculate pi	☐	☐

Explain in your own words the significance of pi

☐☐

Explain your experimental setup

☐☐

Present your results

☐☐

Discuss your sources of error

☐☐

Discuss methods to improve accuracy

☐☐

Cite your references

☐☐

Include pictures as appropriate

☐☐

Write computer code

☐☐

16. What would you add to or change about your report if you were given a second submission?

17. How do you think your report compared to the sampling you saw presented today in the following domains?

	Exemplary	Successful	Average	Below Standard
History of pi	☐	☐	☐	☐
Why pi is important	☐	☐	☐	☐
Clarity of scientific report	☐	☐	☐	☐
Depth of scientific report	☐	☐	☐	☐
Taking multiple measurements	☐	☐	☐	☐
Use of graphs and tables	☐	☐	☐	☐
Accounting for error	☐	☐	☐	☐
Overall discussion	☐	☐	☐	☐

18. If you had to give yourself a grade out of 10, what score would you give yourself and why?

11/30/2021

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