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Flipped-mastery learning through the use of 'student action cycles' in a mixed-ability secondary level Irish science classroom

A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy in the School of Education, Trinity College Dublin

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Robert Clarke

Supervisor – Professor Colette Murphy

Declaration

I hereby declare that this is entirely my own work and that it has not been submitted as an exercise for the award of a degree at this or any other University.

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Robert Clarke BSc, BEd, BSc(hons)

Dated 28/10/2020

Abstract

The following document explores the use of student action cycles (SACs), a reflexive, student-driven approach to flipped-mastery learning, with a focus on developing deep understanding rather than on learning to pass examinations, to address the learning intentions of the 2016 specifications for junior cycle science.

The views of students, with regard to their general educational experience, were examined through the use of several surveys, exit tickets and focus group discussions. In addition to this, comparisons were drawn with data from the Trends in International Mathematics and Science Study, (TIMSS). Science reasoning tasks, (SRTs), were used to examine the cognitive level of students, and the results from these were compared against those from Drumcondra reasoning tests, CAT-4, (cognitive ability test-4), and performance in English, mathematics and science junior certificate examinations. Mindset was also investigated, through the application of two instruments.

The results from this study detailed a fascinating picture, with regard to student experience, and provided a number of recommendations for improved practice. Diploma disease, the drive for accreditation, was observed to have an influence on both the depth of study, and the method of instruction preferred by students. Levels of cognition were found to have declined, in comparison to previous data, indicating that students' general level of processing of reality has deteriorated. Mindset, the belief as to whether intelligence and talent are fixed or malleable, was found to be a static trait, in direct contradiction of the established position. The syllabus for junior cycle science was revealed to be more favoured than its predecessor, the junior certificate science syllabus; although the terminal examination met with some criticism, when examined by leaving certificate students. The student action cycles, (SACs), that were central to this study were highly regarded, and shown to increase collaboration.

Acknowledgements

It is hard to believe, looking back now, that this thesis is the result of the best part of a decade's worth of inquiry; and a lifetime worth of experience. I would like to take this opportunity to thank all of those who have made this journey possible.

First off, huge thanks are due to Professor Colette Murphy for her continued support and confidence in my work throughout this whole process. The way in which you dealt with my queries moved my understanding of the role of a facilitator so much further forward than you will probably ever appreciate; and thanks too to my examiners who offered such helpful suggestions.

Second, and without whom the journey would not have been possible, thanks to all of the members of the school community in which this study was completed. For those that gave permission, those that engaged with aspects of the research, and for those that gave their support .… many thanks.

My wife and family have lived with my head in a computer for years without complaint. Thanks in particular to my wife, my life partner, Dr. Theresa Tallon for her continued support …. and bullying when I seriously considered giving the whole thing up.

Back in 1984, after graduating with a degree in Developmental Biology from Aberdeen University, I disappointed my parents by not proceeding along the doctoral route. I would like to dedicate this thesis to their memory. My father, Dr. Arthur Clarke, and I would regularly compete to complete 'The Scotsman' crosswords, which gave me my life-long interest in the words of others. To both of them, my mother, whose doctoral intentions were preempted by World War II …. I would like to offer Ecclesiastes 3.

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List of Abbreviations

21CLD	21st Century Learning Design
A*a*L	Assessment *as* learning
A*f*L	Assessment *for* Learning
A*o*L	Assessment *of* learning
AMS	Accelerator mass spectrometry
CASE	Cognitive Acceleration through Science Education
CAT4	Cognitive Ability Test-4
CBA-1	Classroom based assessment 1, the EEI
CET	Cognitive evaluation theory
CSMS	Concepts in Secondary Mathematics and Science Programme
DMI	Dweck Mindset Instrument
DMQ	Diehl's Mindset Quiz
DRT	Drumcondra Reasoning Test
DTI	Diffusion tensor imaging
EEI	Extended experimental investigation
ESRC	Economic and Social Research Council
ESRI	Economic and Social Research Institute
FJC	Framework for junior cycle
FoQs	Features of quality
GCSE	General Certificate of Secondary Education
HEA	Higher Education Authority
HIFAS	How I feel about school
IBL	Inquiry-based learning
IDZ	Intermental development zone
IQ	Intelligence quotient
ISTA	Irish Science Teachers Association
JCSS	Junior certificate science syllabus
KMOFAP	King's Medway Oxford Formative Assessment Project
KS3	Key Stage 3

KS4	Key Stage 4
KWt	Kruskal-Wallis test
L_2L	Learning to learn
LA	Learning autonomy
LES	Learner empowerment scale
LH2L	Learning How to Learn
LIT	Learned industriousness theory
MRI	Magnetic resonance imaging
NCCA	National Council for Curriculum and Assessment
Ofcom	Office of Communications
OIT	Organismic integration theory
OSOS	Open Schools for Open Societies
PET	Positron emission tomography
PME	Professional masters of education
PoS	Programme of study
Rg score	Residualized gain score
ROSE	Relevance of Science Education
SACs	Student action cycles
SAILS	Strategies for Assessment of Inquiry Learning in Science
SATs	Standard Assessment Tasks
SDT	Self-determination theory
SEC	State Examination Commission
SIMS	Situation motivation scale
SJCS	Specification for junior cycle science
SLOG	Student Learning Orientations Group
SLS	School Leavers Survey
SOLO	Structure of the Observed Learning Outcome
SRSC	Student Review of the Science Curriculum
SRTs	Science reasoning tasks
SVS	Subjective vitality scale
TLRP	Teaching and Learning Research Programme
ZPD	Zone of proximal development

Chapter 1: Introduction

1.1 Background to the study - A rationale for change

> Science is a collaborative and creative human endeavour arising from our desire to understand the world around us and the wider universe. Essentially, it is curiosity in thoughtful and deliberate action. Learning science through inquiry enables students to ask more questions, and to develop and evaluate explanations of events and phenomena they encounter.
>
> (NCCA, 2015, p.2)

Thus begins the rationale section of the new specification for junior cycle science, (SJCS), published by the National Council for Curriculum and Assessment, (NCCA); an enlightening and empowering statement that clarifies intent for the document that replaced its predecessor, the 2003 junior certificate science syllabus (JCSS), a course that in itself was “activity-based in its design and emphasizes practical experience of science for each individual student”, (NCCA, 2003, p.3).

Although the JCSS had been designed to promote ‘activity-based’, student-centred pedagogies, in the decade following its inception, evidence from a number of sources (Eivers, Shiel & Cheevers, 2006; Shiel, Perkins & Gilleece, 2009; NCCA, 2013) indicated that the perceptions of the purpose, and experience of the subject, were at odds with these intentions and highlighted “the perceived divergence that has emerged between the intended curriculum and the enacted curriculum” (NCCA, 2013, p.1). It had become apparent that somewhere in the translation of the document into practice the message had been lost, as it was reported that classroom instruction was still largely oriented towards the rote memorising of factual information to pass examinations, without creativity, collaboration, curiosity, deep understanding or the application of skills; this despite the JCSS' advocacy of 'learning to learn' (L_2L) strategies.

Not unsurprisingly, secondary science curricula are designed to build on and extend the experiences of primary students, by introducing concepts of greater intellectual demand, as appropriate to the progressive cognitive development of the child, (Piaget, 1977). However, a number of researchers, including this author, have identified that the level of cognitive development required for meaningful engagement with some areas of curricula, such as the JCSS, had not developed in a significant proportion of the students to whom it was delivered; and that for many, these cognitive skills were still undeveloped by the time they entered tertiary education (Wylam & Shayer, 1978; McCormack, 2009; McCormack, Finlayson & McCloughlin, 2009). A lack of *mental maturity* compounded, in many cases, by a diet of rote learning, feeding in to an assessment-rich system, had resulted in a cohort of students who generally "work to pass, not to know" (Huxley, 1904, para. 75), (Murray & Reiss, 2005; Stobart, 2008).

Research has also shown that students are largely demotivated by teaching strategies such as listening to presentations, copying or taking notes, and reading from textbooks (Murray & Reiss, 2005). In addition, few opportunities for meaningful, practical engagement with curricula were reported (Rocard *et al*., 2007; NCCA, 2013) when teaching was largely focused on accreditation rather than on fostering curiosity, enjoyment or life-long learning; "Indeed, there is a strong negative correlation between students' interest in science and their achievement in science tests." (Osborne & Dillon, 2008, p.7). Embodied within the SJCS however, are the social key skills, (referred to internationally as key competencies, or 21st century skills), of working with others, communicating and staying well. The development of these requires the social constructivism of classroom dialogue amongst students, and between students and teachers, with an associated reduction in the use of more 'traditional' didactic methods. The NCCA has gone as far as stating that:

> The junior cycle allows students to make a greater connection with learning by focusing on the quality of learning that takes place, and by offering experiences that are engaging and enjoyable for them, and relevant to their lives. These experiences are of high quality: they contribute directly to the physical, mental and social wellbeing of learners; and where possible, provide opportunities for them to develop their abilities and talents in the areas of creativity, innovation and enterprise.
>
> (NCCA, 2015, p.1)

In an endeavour to address the detail of the preceding three paragraphs, namely how to provide a creative, collaborative, social constructivist experience of science where cognitive development and deep learning are driven by student curiosity, the author has created the concept of student action cycles, (SACs); a student-centred approach for mastery learning. Thus, this thesis documents the attempts to amalgamate and implement the ideas and findings of research cited within the literature review that follows, on motivation and the use of rewards, cognitive development, assessment styles and meaningful learning strategies within the context of the framework for junior cycle, (FJC), (Department of Education and Skills, 2015) such that "The whole is other than the sum of the parts" (Koffka, 1955, p.56). The intention is to design, test and evaluate a model of facilitated learning using SACs that might help to promote curiosity, develop scientific literacy and engagement for life-long learning through a potentially motivational student-centred delivery of the SJCS.

1.2 Flipping the classroom to promote student-centred learning

Dewey's, (1938/1997), discussion of experiential learning in "Experience and Education", reignited a long-standing dialogue between practitioners, over the advantages and shortcomings of progressive hands-on learning strategies, as opposed to traditional lecture-style instruction, that runs deeper than a simple consideration of what to do and when, as this debate has, at its roots, the tenets of constructivism and behaviourism; which have been generally considered incompatible ideologies. This author contends that flipping the classroom might hold the potential to reconcile this debate.

What flipping the classroom essentially does is provide opportunities for structured, experiential learning in school and complimentary, instructional materials for home; or from whichever location the student wishes to access them from for that matter, (Baker, 2000; Lage, Platt & Treglia, 2000; Bergmann & Sams, 2012). In principle, the process is nothing new as educators have always been able to flip learning by providing students with information to digest before developing and consolidating this through practical and social interaction in class. What is new is that since the so called 'digital revolution', it has become possible to provide instructional materials for students, exemplified by the video lectures and podcasts of Khan Academy, (https://www.khanacademy.org), and this author, (http://confeyscience.com), that are potentially more palatable than text books to the 'digital natives', or the 'net generation', of the 21st century. It also allows for possibly more effective use of student/teacher contact time.

> since video lectures are as effective as in-person lectures at conveying basic information, the wisdom of using student and instructor time for live lectures is questionable. Rather, pre-recorded lectures can be assigned to students as homework, leaving class time open for interactive learning activities – activities that cannot be automated or computerized.
>
> (Bishop & Verleger, 2013, p.3)

There is indeed some evidence that non-linear, interactive multimedia instructional material may enhance student engagement and improve learning effectiveness, (Tapscott, 1999; Brown, 2000; Zhang *et al*. 2006), while other research, (Concannon *et al*. 2005; Taneja *et al*. 2015), has shown the opposite to be true. It has also been reported that students' preferences vary depending on how they envisage the route to successful task completion, and on prior experience with a particular approach. It must also be noted that there are dangers in making generalisations, as there is scant evidence for homogeneity in digital competences, or confidences, within the 'net generation', (Bennett *et al*., 2008).

One additional advantage of recorded instruction is the ability to repeatedly review content, and so facilitate movement of information from working to long-term memory, but this treatise proposes that the true strength in flipped-learning lies in how the freed-up classroom time that flipping provides might be used more effectively to promote autonomous, deep learning through the use of reflexive student action cycles, (SACs). SACs are intended to promote mastery learning, (Bloom, 1968); an effective integration strategy that facilitates each and every individual's progression towards attainment at a pace best suited to their own proficiency. It will be argued that this pedagogy might have the potential to open up assessment from simply criterion testing against learning outcomes to the use of a variety of instruments to look at students' abilities to synthesise, evaluate and analyse information as well.

Tomei, (cited in Osborne & Dillon, 2008), discussing science education in Europe, nicely sums up the author's rationale for using SACs to deliver science within the framework for junior cycle as follows:

> The challenge therefore, is to re-imagine science education: to consider how it can be made fit for the modern world and how it can meet the needs of all students; those who will go on to work in scientific and technical subjects, and those who will not.
>
> (Osborne & Dillon, 2008, p.5)

It must however always be borne in mind, as outlined in this thesis, that there have been many initiatives introduced across the World over the years to meet this challenge and that:

> Tempting as it is to change the nature of science education in schools in the belief that it is *the* way to change students' outlook on the physical sciences, history suggests it is unlikely to be successful. Indeed, in the past there have been many curriculum innovation projects that have sought to change/revitalise school science education, but few if any have had long-term success.
>
> (Matthews, 2007 p.85 italics in the original)

1.3 Research overview

The purpose of this research is to evaluate whether student action cycles, (SACs), impact on autonomous learning, in science classes with junior cycle students, by analysing responses to the following research questions:

> How closely do specific pedagogical approaches align with students' perceived educational needs and attitudes towards science?
>
> Do student action cycles impact on student collaboration?
>
> Do student action cycles impact on cognitive development?

The first question will be addressed through the use of a forty-six item Likert-scale questionnaire, developed by the author, called, 'How I feel about school', (HIFAS); based in part on the high school version of the learning and study strategies inventory (https://www.hhpublishing.com/ap/_assessments/LASSI-HS.html). This will examine student perceptions around extrinsic or intrinsic motivation, diploma disease, resilience, flow, social constructivism, self-regulation and goal setting and finally, curriculum content. In addition, responses to statements from the 2015 and 2019 Trends in International Mathematics and Science Study student questionnaires, (TIMSS), (https://timssandpirls.bc.edu), and exit ticket data will be analysed. These will look at engagement and attitudes, enjoyment, confidence and whether students value the subject. The student voice will assist in the interpretation of responses.

Student collaboration is the focus of the second research question and this will be assessed through the use of a rubric designed by the author, based around assessment strategies incorporated into SAILS, (Strategies for Assessment of Inquiry Learning in Science), and material produced by the 21st Century Learning Design partners, (21CLD), (https://www. sri.com/work/projects/21st-century-learning-design-21cld).

The final research question, looking at cognitive development, will make use of several of the science reasoning tasks, (SRTs), developed by the Concepts in Secondary Mathematics and Science Programme, (CSMS), (Shayer & Adey, 1978). These will be used, as extensive data is available for comparison, both historical and current, from Ireland and around the World, for school and university students.

To support development of the SACs, and meaningful engagement with the learning outcomes of the specification for junior cycle science, (SJCS), (NCCA, 2015), a modified version of some of the original *Thinking Science* program (Adey, Shayer & Yates, 2001), of cognitive acceleration materials, will be incorporated into the structure of the SACs. The taxonomies for analysis of curriculum demand, developed by the CSMS programme, (Shayer & Adey, 1981), will be also used to develop a logical and accessible three year programme of study, (PoS), founded on the eight principles for junior cycle education, the twenty-four statements of learning from the framework, literacy, numeracy and the other six key skills of junior cycle (NCCA, 2012) and the learning outcomes from the five strands of the SJCS.

Assessment *for* Learning, (A*f*L), will be extended to incorporate the research findings of the King's Medway Oxford Formative Assessment Project, (KMOFAP), which developed and recommended the more student-centred approach of learning how to learn, (LH2L). An adapted version of the Structure of the Observed Learning Outcome, (SOLO), method for assessment, will be used to evaluate the quality of learning along with performance against established success criteria, and the features of quality, (FoQs) from the SJCS.

1.4 Thesis structure

This thesis is divided into six chapters, the first of which has introduced the study, located it within the general context of secondary education in Ireland, and given the rationale and background. Chapter two opens with a theoretical framework as an introduction to a review of literature that the author regarded to be pertinent to the development of student action cycles, (SACs). Particular focus will be paid to motivation, cognitive development, assessment and meaningful learning strategies. Reasons for the inclusion of a variety of the recommendations highlighted in this chapter will be explained in the conceptual framework that follows. In chapter three, the rationale for the research method adopted is described, along with information about data collection methodologies. Chapter four presents the results obtained for each of the research questions. The penultimate chapter attempts to draw together the findings from the preceding chapter and relates these to the literature review and conceptual framework. The concluding chapter summarises the main findings of the research in an attempt to provide insight into the effects of the use of student action cycles. This chapter also highlights the limitations of the study and suggest areas for further research.

Chapter 2: Literature review

2.1 An introduction and theoretical framework

Much has been written about the flipped-classroom model, but a large proportion of this focuses on the external video/audio component rather than on how the process facilitates education *within* schools. By largely removing the *traditional* style, instructional transmission of information *to* students from the classroom, time can be made available for a variety of approaches that might better facilitate learning in its most broad sense.

The focus of this research is on an attempt to use freed up time, generated by flipping the classroom, to increase scientific literacy and meaningful, enjoyable engagement with the specification for junior cycle science, (SJCS), (NCCA, 2015), through the use of student action cycles, (SACs). To inform this study the literature review is divided into four sections that each describe areas of research that the author regards as pertinent to the design of SACs.

The diagram that follows, (Figure 2.1), illustrates how components of the four sections of the literature review combine to form the theoretical framework that informs the structure of the student action cycle approach.

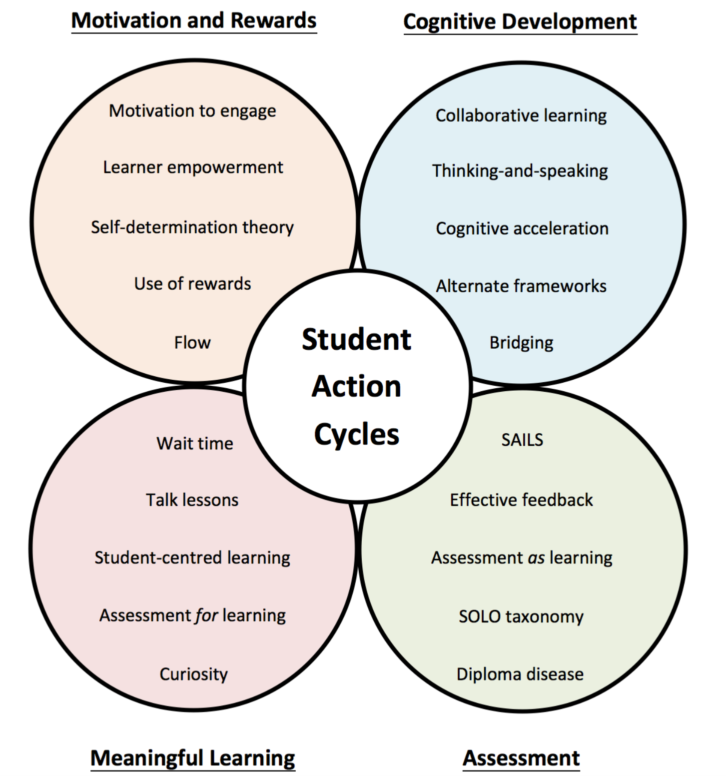


Figure 2.1 The theoretical framework for Student Action Cycles, (SACs)

The first section examines student motivation and the use of rewards. It reviews a number of theories put forward to explain why students want to learn and what can be done to foster and maintain this interest.

The second section reviews the topic of cognitive development, and asks whether the student cohort in general, and individuals within it in particular, are ready to engage meaningfully with particular learning outcomes of the specification; and if not, how cognitive growth to remedy this might be facilitated.

Assessment is the focus of the third section and covers the work of a number of authors on various strategies that have been argued to improve the students' scholastic experience by moving from the summative assessment of rote learning to formative assessment for life-long engagement with education.

In the penultimate section, a number of meaningful learning strategies, that have been trialled by other researchers, are discussed and a reasoned basis for their inclusion within the SACs model is given.

The final section of the literature review combines the content of the previous four to describe the conceptual framework of student action cycles and their use in attempting to develop flipped-mastery learning in a mixed ability secondary level Irish classroom.

2.2.1 Motivation and rewards – a flight-plan

In the sections that follow, the author introduces a number of theories, and the results of several research projects, that he regards as pertinent to the motivation and rewards component of the theoretical framework for student action cycles. The graphic, on the next page, (Figure 2.2), is an attempt to clarify how the information presented fits together; and also how certain elements might have a modifying effect on others.

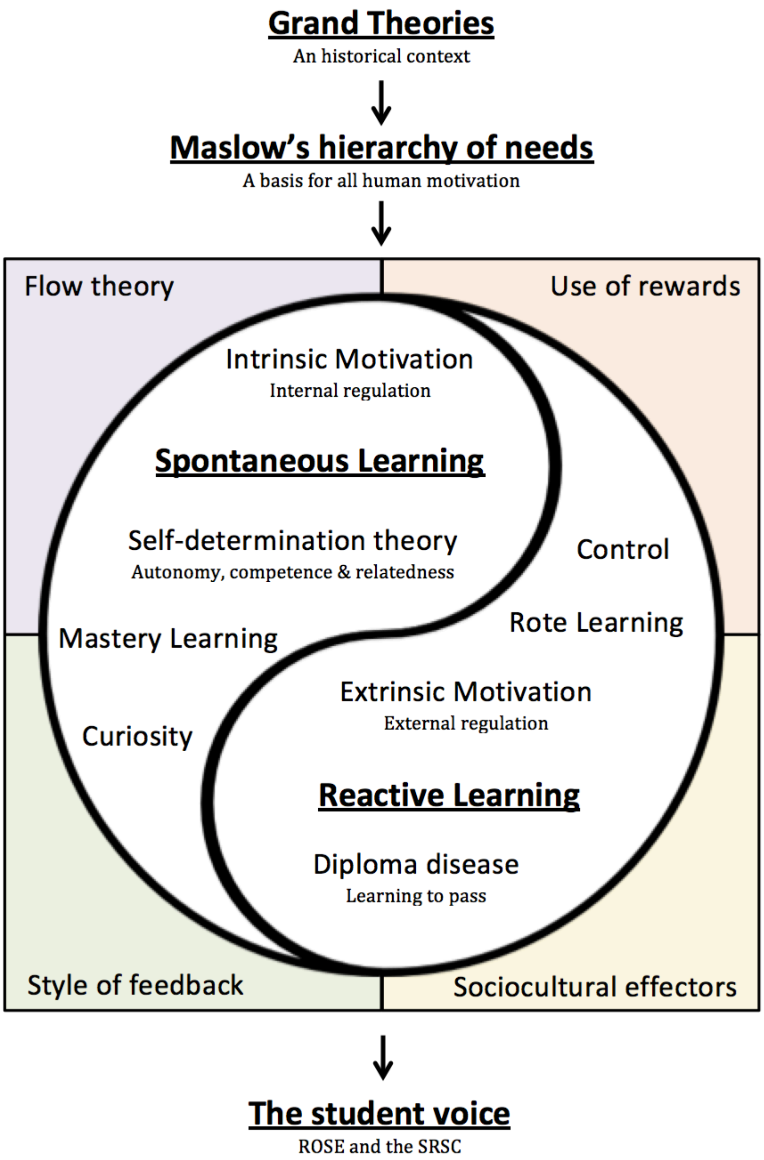


Figure 2.2 The interaction between elements of the literature review covering motivation and the use of rewards

2.2.2 An Introduction to Motivation

There are three things to remember about education. The first one is motivation. The second one is motivation. The third one is motivation.'

(Bell, cited in Ames, 1990, p.1)

For well over two thousand years, from the time of the Grecian philosophers, such as Socrates, Plato and Aristotle, to the mid twentieth century, so-called ‘grand theories’ of motivation held sway. These theories attempted to ascribe *every* facet of motivation to a single cause.

One of the earliest examples of a grand theory, dating from around 350BC, is the Aristotelian ‘appetitive’ ends versus means thesis that proposes that organisms actively and hedonistically strive to achieve *satisfaction*, whether this be material, cognitive or spiritual, while equally actively attempt to avoid adversity and disappointment.

In the seventeenth century, Descartes, who regarded humankind as unique within the living world, separated the cognitive functions of the mind from the material functions of the body, and regarded the free choice of *will* as the source of motivation. He argued that in exercising *will*, individuals have the choice to pursue or avoid goals based on the mental functions of memory, understanding and imagination, and that amotivation, or indifference, results from a lack of knowledge or appreciation of the possible outcomes of a particular choice. However, it has been argued that the vagaries of free choice make Descartes’ explanation of motivation too unpredictable for a universal theory.

Just over two hundred year later, and overturning Descartes’ human/animal and mind/body dichotomies, McDougall, (1950), the founder of hormic psychology, suggested that animalistic impulses, or instincts, could be the explanation for all motivated behaviour. In support of Lamarck's theory of the inheritance of acquired characteristics, and in rejection of Darwinism, he proposed that a set of seventeen innate goal directed responses to external stimuli have become hard-wired into all sentient Life through the process of mind-guided evolution. He called this instinct theory, and in reference to human psychology, divided each instinct into perception, behaviour and emotion. In illustration, when responding to the hunger instinct, a person is more likely to notice the aroma of food, will then move to search out the source, exerting energy in an emotional drive that links perception to behaviour.

Instinct theory was also popular with James, (1905), who had inspired McDougall to study psychology. He was a firm believer in Darwin's theory of evolution however, and felt that instincts have an important role to play in survival; and that instincts could also evolve through the process of natural selection. This theory's acceptance eventually declined though, after the listing of over six thousand instincts, and the belief that all but the most very basic of these could be modified by experience and the environment, (Degler, 1991). There was also the problem of the circular argument that cause elicits a behavioural response, while the behaviour in itself is taken as evidence of the cause; in addition it was noted that some behaviours appear in certain circumstances but not in others.

In a modification of instinct theory, the life instinct, and eventually death drives, (which replaced ego), were introduced by Freud, (1922), as explanations for all motivated behaviour. The life instinct, (*Eros*), relates to survival strategies, reproduction and pleasure, and sits in opposition to the death drives, (*Todestriebe*), of aggression, compulsion and self-destructiveness. In post-Freudian analysis *Thanatos*, the Greek god of death, replaces *Todestrieb*, as the complementary antagonist to *Eros*, the god of love. Understandably, life and death as stimuli have been regarded as unsatisfactory explanations for many examples of motivated behaviour.

Drive-reduction theory, (Hull, 1943), is considered to be the last grand theory, and describes motivation as actions taken to reduce, and hopefully satisfy, the unpleasant effects of drives such as thirst, hunger, fear or a need for shelter. It has been described as a state of arousal initiated by negative homeostatic perturbations; that is to say there is motivation to remove tension by satisfying needs, and hence restore balance. Hull believed that this process mirrored the way in which biological systems maintain balance and later went as far as developing a mathematical formula that he hoped would explain all human behaviour.

A result of the decline in prominence of these 'one-size-fits-all' global theories has been a burgeoning of mini-theories that attempt to explain particular motivational phenomena at a much more limited, local level. The following reviews a number of these and their application within the context of education. It also briefly examines the role of curiosity in motivation, contains a short study of students' perceptions of their educational experience and the examination system, and concludes with a brief discussion of the potential relationship between aspects of these mini-theories and the research questions.

2.2.3 ‘A Theory of Human Motivation’

In the midst of the Second World War, the American academic, Maslow, proposed that an inherent desire to satisfy a hierarchy of needs forms the basis for all human motivation. He identified physiological needs, such as hunger and thirst, to be the most basic, and prepotent to all others, suggesting that only when these needs are at least partially satisfied could others, like the need for safety, determine behaviour. In reference to the needs of the child he included injustice, unfairness and inconsistency as detrimental to feelings of safety and suggested that children desire the stability and predictability of organized routine. The love need appears next in Maslow’s hierarchy, characterized by the desire for the interpersonal feelings of belonging. Once at least partially satisfied, motivation drives actions to fulfil the esteem need, the wish to be accepted and valued by others. Maslow separated the need for self-respect, or self-esteem, from the need for respect from others and considered self-esteem to bring with it feelings of “self-confidence, worth, strength, capability and adequacy of being useful and necessary in the world.” (1943, p.382). He originally imagined the ultimate goal of humans to be the need for self-actualization stating, “What a man *can* be, he *must* be.” (1943, p.382 italics in the original), but in later writings included his Theory Z, (1971, p.271), where he divided self-actualizers into those whom are content to live in the concrete, here-and-now, mundanity of the doing, D-realm, from others with the need to transcend to the creative B-realm of being. This same creativity is echoed in the highest level of Anderson and Kratwohl’s revision of Bloom’s taxonomy. Maslow commented that the fixed, ordered nature of his hierarchy could be affected by circumstances and cultural differences.

2.2.4 Intrinsic and extrinsic motivation

Intrinsic motivation is the desire to perform an activity for which there is no apparent reward apart from the enjoyment or satisfaction in the task itself. The term was first adopted by Harlow, (1950), after observing Rhesus monkeys enthusiastically working to solve simple puzzles in the absence of either of the two motivational drives identified by psychologists at that time; namely the biological drive for food, water and sexual satisfaction, or the external rewards and punishments of the environment.

Extrinsic motivation, on the other hand, is imposed on an activity by some external event, or entity, in the form of tangible rewards, sanctions or verbal responses. Deci, (1971), argues that intrinsic motivation provides for autonomy, while extrinsic motivation is controlling and coercive, and questions whether coercion is beneficial. He refers to the work of deCharms, (1968), who suggested that an individual who is initially intrinsically motivated may become demotivated if provided with externally mediated rewards as:

> the locus of control or the knowledge or feeling of personal causation shifts to an external source, leading him to become "a pawn" to the source of external rewards.
>
> (Deci, 1971, p.105)

Deci hedged his bets though, by suggesting that an external reward might enhance motivation through reinforcement of the activity in accordance with Thorndike's, (1898), law of effect, or indeed, have no impact.

In reference to motivation within a social constructivist model, Sivan describes this as "a socially negotiated process that results in an observable manifestation of interest and cognitive and affective engagement", (1986 p.210). Crucial to this are the student's *interest* and *engagement*; this drives student-centred, spontaneous learning, or learning for the sake of learning, rather than reactive learning, which is teacher directed.

Experiments in operant conditioning by Skinner, (1953), had clearly established that extrinsic rewards can modify behaviour but what is significant is that, according to Deci *et al*. (1999), in the twenty years that followed the publication of Skinner's research, the results of "hundreds of studies", (p.627), show that these effects only persists as long as rewards are given. On termination, behaviours return to the pre-reward baseline.

In their meta-analysis, (n=128), of the effects of rewards on intrinsic motivation Deci, Koestner and Ryan reveal that, "engagement-contingent, completion-contingent, and performance-contingent rewards significantly undermine free-choice intrinsic motivation", (1999, p.627). Furthermore, engagement-contingent and completion-contingent rewards were found to reduce student interest in the task at hand. The presence of any rewards or the expectation that these would be forthcoming was also found to impair both motivation and interest, particularly with children, but also with college students. However, Karniol and Ross, (1977), recorded increases in motivation for poor performers, when non-contingent rewards were given, and suggested that this was because these rewards negated feelings of failure or negative self-worth.

Negative effects of rewards on motivation were also noted by Ariely, (2008), who reported on three separate studies were he found that, as long as the task was routine and mechanical, rewards worked as expected; that is to say the greater the incentive, the better the performance. However performance deteriorated on tasks with even a rudimentary level of cognitive demand when rewards were given. Similarly, Amabile, (1985), showed that creative writing was undermined and depersonalized by a focus on extrinsic rewards. Add to this, the analysis by Bénabou and Tirole, (2003), that showed that in the short-term incentives act as weak reinforcers, but in the long-term, as demotivators. In general then, evidence from a variety of studies shows that contingent motivators of the 'if… then' type with mechanistic rewards, or punishments, narrow focus and impair creativity.

It was reported by Ryan and Connell, (1989), that:

> the more students were externally regulated the less they showed interest, value, and effort toward achievement and the more they tended to disown responsibility for negative outcomes, blaming others such as the teacher
>
> (cited in Ryan and Deci, 2000, p.73)

Eisenberger and Cameron, (1996), took an alternate perspective on results showing negative impacts of rewards stating that the conditions which generated these were highly restricted and easily avoidable. They quoted the work of Deci and Ryan and continued that rewards contingent on task completion, or those that are performance-independent, are most likely to be detrimental to intrinsic motivation while those rewards that are quality-dependent, although possibly reducing autonomy, may increase feelings of competence and hence stimulate intrinsic motivation. Dickinson also stated that any decline in intrinsic motivation, or creativity, caused by employing reward systems is temporary and can be avoided completely “if extrinsic rewards are reinforcing, noncompetitive, based on reasonable performance standards, and delivered repetitively”, (Dickinson, 1989, p.1).

The unnecessary use of rewards to motivate students to complete interesting tasks was investigated by Lepper *et al*. (1973), who stated, in their overjustification hypothesis, that if a person is induced to complete an enjoyable task for reward then the reward is likely to become the focus of attention, rather than the task. Their study observed pre-school children’s, (n=51), interest in drawing with ‘magic markers’, which were a novel inclusion to normal classroom equipment. They set up three conditions, namely no reward, an unexpected reward and prior notification that good work would be rewarded. In follow up observations they noted that the no reward and unexpected reward groups showed a slight increase in interest, but those with an expectation of receiving the reward showed a marked decrease. The group did propose however, that extrinsic rewards might increase intrinsic interest in activities that students have little initial interest for, or where a degree of mastery through perseverance is required, before the attractiveness of the activity is revealed.

Satiation with a task can understandably lead to decreased motivation. This was suggested by Eisenberger and Cameron, (1996), as an alternative explanation for the reduction in free-time drawing by the children in the ‘magic marker’ study. In addition Balsam and Bondy, (1983), suggested that removal of the reward could have been seen as a punishment and this might have had a negative effect. They also argued that performance independent rewards, where individuals realize that they have no control over the reward conditions, might decrease intrinsic motivation as they foster 'learned helplessness'.

Finally, Ferlazzo, (2013), suggests that, whatever the circumstances, it would be wise to avoid the use of rewards to incentivise motivation, as he equates this to a quick-fix approach similar to the casting of a spell on the broom in Goethe's poem, the sorcerer's apprentice. Initial effects may be positive, but these are likely to diminish in the long term. He concludes that students' motivation is best enhanced when they are given autonomy, and ownership of their learning.

The negative effects of aversive control will not be discussed, other than to comment that several research groups have recorded the expected demotivated outcomes such as anger and aggression, (Bandura, 1969), emotional withdrawal, depression, truancy and work avoidance, (Balsam & Bondy, 1983).

2.2.5 The influences of autonomy, competence and relatedness

Autonomy, competence and relatedness are identified by Ryan and Deci, (2000), in their self-determination theory, (SDT), as necessary requirements for intrinsic motivation.

Autonomy is to act with a sense of freedom of choice or volition, which should not be confused with independence, which is functioning on one's own without reliance on others. Feeling autonomous correlates well with Ryan and Fredric's, (1997), subjective vitality scale, (SVS). According to Khalkhali *et al*. (2012), when subjective vitality scores are high students experience positive feelings of being alive and alert and full of energy. They recorded such values in physical education classes where students had high levels of autonomy; but when this was absent sensations of irritability and fatigue, linked to lack of control, were reported.

Improvements in rote learning performance were recorded by Grolnick and Ryan, (1987), when autonomy was reduced, but this was also coupled to a lower long-term recall. Conversely, they report that when autonomy was encouraged, conceptual, mastery learning was promoted. They concluded that the active processing and organisation of information, that is essential for meaningful learning, is most likely to occur when autonomy is afforded.

Another facet of autonomy is ownership, as exemplified by the endowment effect, (Kahneman *et al*., 1991), which was investigated by Knetsch and Sinden, (1984). The pair reported that individuals were less inclined to accept compensation to relinquish an owned item than they were to pay an equivalent amount to purchase the same.

Competence is the perception that an individual has an inherent capability to master interactions with their environment. Pintrich, (2003), argues that such mastery interactions are a strong motivational force; events that promote feelings of competence will enhance motivation. Seifert, (2004), identifies two possible, but diametrically opposed, behavioural outcomes that may arise from perceptions of high competence; namely mastery learning and work avoidance. He also suggests that 'learned helplessness' is a corollary for those who regard themselves as incompetent, and that with this comes diminished intrinsic motivation. Formative assessment that reinforces competence should reduce 'learned helplessness'. Feelings of competence may be enhanced by the provision of informative feedback that maintains an internal locus of causality, as intrinsically motivated behaviour allows a person to feel self-determining. Controlling feedback generates an external locus and diminishes intrinsic motivation while promoting compliance or defiance.

Relatedness, (Baumeister & Leary, 1995), a restatement of Maslow's love need, (section 2.2.2), is the desire to feel connected with others; a sense of belonging in a social context where everything connects.

2.2.6 Expanding on self-determination theory

> Most human motivation is cognitively generated. People motivate themselves and guide their actions anticipatorily by the exercise of forethought
>
> (Bandura, 1993, p.128)

By 1971, Deci had expanded on the original aspects of self-determination theory, (SDT), referred to in the previous section, by suggesting that responses to different rewards may be variable and based on an individual's assessment of the reward's worth. He described this in his cognitive evaluation theory, (CET), by suggesting that tangible rewards may decrease intrinsic motivation as subjects may interpret that they "should probably not render this activity without pay," (1971, p.107). They move the locus of control away from the individual and there is a danger that these might subsequently become the sole reason for performing the activity. This, Pink describes as the *Sawyer effect,* (2009, p.37), namely "practices that can either turn play into work or turn work into play". If verbal rewards and social approval are used instead, the subject might regard these as less coercive and consequently be less likely to re-evaluate the worth of the activity.

Cognitive evaluation theory has not been without its critics however. A small meta-analysis, (n=20), conducted by Wiersma, (1992), on the effects of extrinsic rewards on intrinsic motivation, reported that while some studies supported CET an almost equal number did not. In addition to this, Carton, (1996), has raised issues with much of the research that is claimed to support CET by stating that issues of temporal contiguity, the frequencies of rewards, and the ability of subjects to evaluate the likelihood of the same being forthcoming are ignored, and that the results could also be interpreted to support operant theory instead.

In 2008, Deci and Ryan introduced their organismic integration theory, (OIT), to describe how external motivators differ in their effect on motivation. This was developed from SDT and CET and their self-determination continuum, (Ryan and Deci, 2000), (Figure 2.3), which has amotivation at one end and intrinsic motivation at the other.

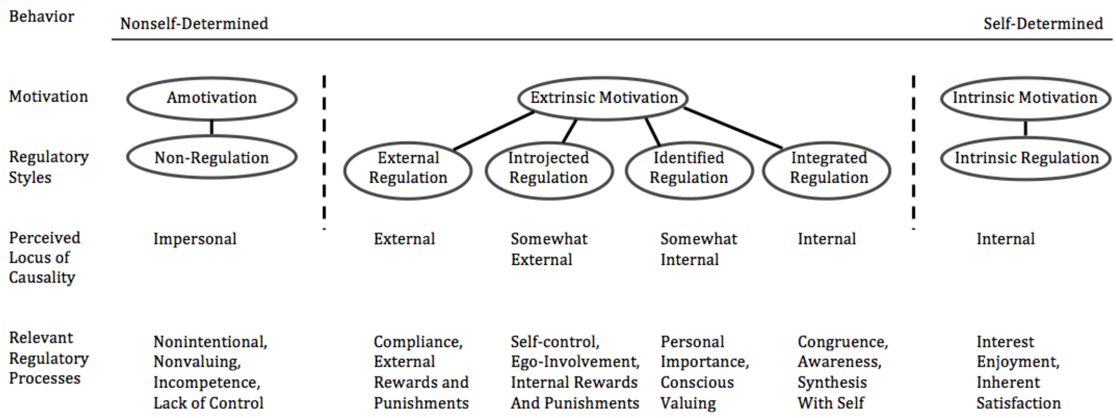


Figure 2.3 The self-determination continuum showing types of motivation with their regulatory styles, loci of causality, and corresponding processes, redrawn from the original in Ryan & Deci, 2000 p.72

Extrinsic motivators that are most controlling deny autonomy, as the locus of causality is external. This is external regulation and is the basis of studies by operant theorists such as Skinner.

Introjected regulation, the second category of OIT, revolves around self-esteem and ego-involvement. Motivation is internal but the locus of causality is perceived as external and activities are undertaken to avoid guilt, or to receive external praise to bolster a feeling of self-worth.

More autonomously driven is identified regulation, where externally imposed goals are repeatedly evaluated and perceived as personally important and thus accepted.

Integrated regulation is when external regulation or goals are fully assimilated, after being evaluated and gauged as being congruent with the individual's own values and needs. This final category most closely resembles intrinsic motivation, but is separate in that the driving forces are not interest, enjoyment or inherent satisfaction.

Empowerment, defined by Thomas and Velthouse, (1990), as increased intrinsic motivation, is a cognitive model that combines the elements of sense of impact, competence, meaningfulness and choice. Impact involves perceptions of purposefulness such that actions make a difference within the individual's proximal environment. Meaningfulness refers to an evaluation of the worth of a task in relation to one's own perceptions, and could be considered synonymous with task relevance. Competence is self-explanatory and choice is an expression of autonomy. In essence the model subdivides Deci and Ryan's SDT categories of autonomy and competence. Possibly unsurprisingly Brooks and Young, (2011), investigating the relationship between student choice, learner empowerment and motivation, discovered that:

> empowerment is highly and positively correlated with intrinsic motivation, and that it is highly and negatively correlated with extrinsic motivation.
>
> (2011, p.55)

An unexpected result of their research was that, under certain circumstances, providing too much choice had negative consequences on motivation, (Iyengar & Lepper, 2000), and confused students, who regarded this as “teacher misbehaviour” (Brooks & Young, 2011, p.57). Instead of feeling empowered by being allowed to select from a large array of options, students became overwhelmed and ended the frustration of the choice making process by making a decision that was often merely satisfactory, rather than optimal. The frustration experienced may then have led to a loss of confidence and a sense of lack of control.

2.2.7 The power of feedback

The effects of task-involving and ego-involving directed feedback, in relation to cognitive evaluation theory, (CET), was investigated by Ryan, (1982), as an extension to the original work. He found that ego-involving feedback, which in essence involves a shift in the locus of causality away from the individual, diminished intrinsic motivation relative to task-involving feedback, which promoted feelings of competence and improved intrinsic motivation.

Additional research into the effects of ego-involving feedback through numerical grades, and task involving comments, further supports Ryan’s position with regard to effects on motivation. Butler, (1988), reports that where grades, or grades and comments, were given negative effects on interest and performance were noted, but when only comments were provided, positive intrinsic motivation was observed. Positive feedback was also found to enhance self-driven engagement and interest but was seen to be less effective when given verbally to younger students, (Deci, Koestner & Ryan, 1999). However, there is a caveat, in an earlier study, Deci *et al*. (1975), had discovered that positive feedback enhanced intrinsic motivation in males but diminished it in females. They put this down to strengthened feelings of competence in males and an autonomy damaging, transfer of the locus of causality away from the individual in females. The underlying cause of these differences, they believed, could be attributed to traditional gender-role socialization practices that encouraged independence and achievement orientated behaviour in boys and more dependent, interpersonally sensitive actions in girls, who looked for praise from external sources.

When the research into the effects of positive feedback on motivation was repeated in the late 1980s, (Vallerand & Reid, 1988), an increase in motivation was observed for both genders; supporting earlier findings of Blanck *et al*. (1984). In attempting to explain the incongruence between their results and those from 1975, Vallerand and Reid referenced societal changes that had reduced gender inequalities. In balance, they did note that other contemporaneous studies, (Zinser, Young & King, 1982), showed support for the findings of Deci *et al*. A potential, differential gender appeal in the tasks used by Deci's group was questioned by Blanck *et al*. (1984), who suggested that the Soma cube, visual-spatial mechanical puzzle used might be preferentially more interesting to boys and the word cubes, verbal skills challenge more appealing to girls. They contend that this might have impacted on Deci's results and note that when they replicated the work, scores were equivalent on what they described as "sex-appropriate tasks", but that if only one type of task had been used, their data would have revealed a difference between the genders in terms of the level of intrinsic motivation. The results of this research showed that with gender appropriate challenges, verbal reinforcement promoted intrinsic motivation in both boys and girls.

High quality teaching involves being cognisant of individual students' dispositions to feedback, as we are reminded from the research by Hattie and Jaeger, (1998), and there are important conceptual variables to consider when making praise statements. Henderlong and Lepper identified the following five as being of greatest importance:

> praise enhances intrinsic motivation and increases perseverance when it is perceived as sincere, encourages adaptive performance attributions, promotes perceived autonomy, provides positive information about personal competence without relying heavily on social comparisons, and conveys standards and expectations that are realistic and not disruptive.
>
> (2002, p.787)

2.2.8 Learned industriousness theory

Learned industriousness theory, (LIT), as proposed by Eisenberger, (1992), is contrary to the principle of least effort espoused by Zipf, (1949), in that it involves avoiding the path of least resistance and expending unnecessarily large amounts of physical or cognitive effort on tasks that could be completed much more easily by doing less. Eisenberger contends that there must be secondary rewards to the individual derived from the sensation of high exertion that reduce the averseness of tasks. A consequence of LIT is that individuals evaluate which elements of a task are rewarding, or rewarded, and then apply high or low effort to these areas in subsequent tasks. As

Eisenberger and Cameron, (1996), identified, low effort when rewarded would be imbued with secondary reward properties and then be preferentially selected in line with the expectations of Zipf's principle. High divergent thinking, associated with creativity, typically involves an additional input of cognitive effort for a longer period of time, over and above that required for conformative tasks. Arising from this assumption Eisenberger and Cameron, (1996), suggested that working hard at being creative might increase creativity through a two-fold effect of the reward, based on the positive sensations of LIT, and also directed attention. In their follow up study, Eisenberger & Selbst, (1994), discovered that where a reward was given for high divergent thinking subsequent creativity was indeed increased; whereas where low divergent thinking was rewarded the opposite effect was observed.

> One simply needs to reward creative performance, rather than trivial performance involving low cognitive effort, to prevent a decremental effect of reward on creativity.
>
> (Eisenberger & Cameron, 1996, p.1162)

2.2.9 Motivational drives and sociocultural effectors

In 2004 Seifert identified self-efficacy theory, attribution theory, self-worth theory and achievement goal theory to be those that he regarded as predominant in the field of educational psychology.

Self-efficacy theory, (Bandura, 1993), addresses the beliefs the individual has as to whether he or she is capable of completing a task. Students who perceive themselves to be able are more likely to be “self-regulating, strategic and metacognitive”, (Seifert, p.138), and pursue mastery goals, while those who believe that success is beyond their capabilities tend to avoid tasks, or behave in a performance orientated way. Seifert discounted this theory as a full explanation for motivation as it does not explain the capable individual who does the bare minimum and is satisfied with a borderline pass, or the student who uses the armour of ‘I can’t do this’ as self-protection when attempting a demanding task. Self-efficacy theory is reminiscent of ideas expressed by Dweck, (1986), around an individual’s perception that ability and intelligence might be either fixed or malleable traits.

Attribution theory, (Weiner, 1985), relates the perceived cause of an outcome to the three dimensions of locus of causality, stability and controllability which give rise to positive, neutral or negative emotions, that in turn influence future motivation. Success attributed to internal, controllable causes is likely to generate positive emotions while the opposite is true for failure resulting from external, uncontrollable events. If failure is seen as the result of an internal, uncontrollable and stable factor, such as the perception of a fixed level of intelligence, (Dweck, 1986; Pintrich, 2003), then the likelihood of academic motivation is low. Weiner argues that high achievers often relate success to an internal locus of causality while poor achievers typically believe they have no personal control of success and so exert less effort.

When considering the profile of a typical Irish classroom it is important to be aware of possible cultural and religious effectors that may impact on the generalisations of any theory relating to student motivation. For example, it has been proposed, that attribution theory does not sit well with an Islamic conception of motivation, (Kamarulzaman, 2012), as Muslims believe that all that is good comes from Allah, the external influence, and all that is negative is a consequence of the individual's bad deeds; that is to say, internal factors. Further illustration of the influence of Islam on motivation can be seen in the month-long fasting (*sawm*) of Ramadan, where Maslow's basic motivational needs of hunger and thirst are ignored, and Jihad, where Maslow's need for safety is disregarded. It has been proposed that Muslims single-mindedly attempt to accomplish Maslow's highest need of self-actualization, in order to please Allah, before considering the other, lower order needs; this would be most easily achieved by pursuing performance, rather than mastery goals. Alias and Samsudin, (2005), argue that the human soul moderates human motivation and that this has been largely ignored in Western psychology. They also comment that the Islamic model of motivation is based on ideal behaviour and that reality influences this, and that although there are points of disagreement, generally:

> every Western theory has some truth and is supported by Islam but has limitation in giving a full picture of human motivation.
>
> (Alias & Samsudin, 2005, p.11)

Self-worth theory, (Covington, 1984), proposes that a primary focus of classroom activity should be the need to maintain a sense of competency and self worth, exemplified in a general perception that high ability equates to worthiness. Covington asserted that teenagers and adolescents tend to regard ability as the main determinant of achievement. He proceeded to suggest that effort only replaces ability where learning for learning's sake is the goal and stated that some students could perceive danger in exerting maximum effort for a task where failure might be the outcome; as the cause would then lie with a lack of intelligence rather than diligence. "From the students' point of view, failure without effort does not negatively reflect on their ability", (Ames, 1990, p.413). Ames' conclusion, like Covington's summary, reflects their Western cultural bias, but Ng, (2003), warns that cultural values and norms should be taken into consideration when considering motivational drives.

Achievement goal theory, (Dweck, 1986; Ames, 1992; Bandura, 1993; Covington, 2000; and Pintrich, 2003), proposes that a primary motivator for learning is a drive to achieve either mastery, or performance goals. Mastery oriented students are characterized by autonomous feelings that internal, controllable factors are the cause of success or failure, that intelligence is not fixed and that work has meaning, or relatedness, (Seifert, 2004). Performance, or ego-oriented, students, on the other hand, are more likely to view intelligence as a fixed commodity and be concerned with how they perform against, and are perceived by, others. Ames, (1992), argues that mastery goal orientations target achievement, while pursuing performance goals is centred on failure avoidance. He proposed that many students enter formal education with a mastery goal mindset but that this rapidly becomes normalized towards a focus on performance goals, rationalizing this by stating:

> When we consider the preponderance of public evaluation practices, normative

> comparisons, extrinsic rewards, ability grouping, and emphasis on production, speed, and perfection, it is no wonder that children find it difficult to maintain a learning or mastery orientation.
>
> (Ames, 1990, p.414)

It has been suggested that it would be better if achievement goal theory avoided the contrast between performance and mastery goals and instead looked at how the two goal foci could be combined to foster motivation and achievement through a multiple goal perspective, (Harackiewicz *et al*., 2002).

Ability as the main causal determinant of success is a Western construct and contrasts with Eastern views that are still largely influenced by the teachings of Confucius. For nearly three thousand years, up until the 1910s, the class to which one belonged, rather than wealth, defined success in Chinese society, (Huang & Gove, 2012). The class system was founded on the four social strata of Confucianism, namely the scholars, (*Shi*), farmers, (*Nong*), workers, (*Gong*), and businessmen, (*Shang*). Current Chinese society still retains the concept that scholars belong to the highest social class and that effort is the key to academic success.

Comparing Western research on achievement goal theory with Asian studies, Ng, (2003), remarked that in the East, mastery and performance goals were always shown to be positively correlated, and that Asian students tended to score higher in performance goals and lower in mastery goals than their Western counterparts. In explanation he offered that education is of highest priority for the Chinese, where the relative performance of a child within a group is of far more importance than the quantity or quality of learning, personal interest or enjoyment. Citing Shek and Chan, (1999), and Salili, (1995), he expands on this with a description of the ideal Chinese child as one who shows filial piety towards parents and is a high achiever in school. Being successful academically is a culturally acceptable way of showing respect to parents and “bringing glory to one’s family.”(Ng, 2003, pp.2-3). Thus, in an Eastern cultural context, learning cannot be extricated from achievement and both learning and achievement are regarded as social obligations. Ng concludes that while able students will work hard to outperform members of their cohort, less able students will also expend high levels of effort to avoid showing a lack of ability and gaining the additional societal stigma of being labelled as lazy.

Within the pluralist society of the twenty-first century Irish classroom, consideration of the sociocultural context of students, and their families, is important in relation to its impact on motivation. Ng contends that:

> Without such consideration, we may be misguided by the western research and motivate the Chinese in a culturally inappropriate manner, for example promoting mastery goals over performance goals and ignoring the potentials of social goals.
>
> (Ng, 2003, p.4)

Ng does suggest that this traditional view is most likely to be held by female and younger students, while male and older students might display a differentiated conceptualization; where the social obligation of performance goals runs in tandem with the mastery goals and personal achievement.

Cultural pressures that impact on education are also still apparent in India and Pakistan, where as recently as 2007, despite constitutional guarantees of universal free education, the implications of class, caste and gender were reported, (Stærkebye Leirvik, 2016).

Indian parents of all classes and castes, like the Chinese, stress the importance of studying hard to bring honour to the family through academic achievement. Education is a highly valued status symbol.

The Indian class system tends to be associated with employment status and income, and is only birth related in terms of the financial implications of the child's parents. Caste on the other hand, is immutable. The caste system has four divisions; the *Brahman*, the scholars and priests; the *Kshatriya*, the warriors and ruler caste; the *Vaishya*, the commercial caste; and *Shudra*, the menial workers. Traditionally the *Shudra* where regarded as untouchables and denied access to formal education.

A study of immigrant Indian and Pakistani students, (n=23), in Norway indicated that belonging to a high caste might diminish motivation; as perceptions of already having 'made it' in society could possibly override the need to compete, (Stærkebye Leirvik, 2016). This the researcher describes as the Don Quixote effect, in reference to the eponymous hero's belief that he is a knight simply because he reads books on chivalry. The study found that other students, who realised that the caste system had little value in their new environment, were highly motivated to succeed; including low caste students who were no longer constrained by their old shackles.

2.2.10 Flow

Maslow, (1964), Privette, (1983), and Csíkszentmihályi, (1992), proposed the positive sensations of peak experience, peak performance and flow respectively as effective motivators.

Peak experiences are periods of intense focus that bring with them an holistic sense of euphoria, according to Maslow; a religious experience that should be regarded as an indication of reaching the goal of self-actualization. He wrote that during such an episode:

> The person feels himself more than at other times to be responsible, active, the creative center of his own activities and of his own perceptions, more self-determined, more a free agent, with more "free will" than at other times.
>
> (Maslow, 1964, p.72, spelling from the original)

Peak performance is described by Privette as functioning at a high level that "is more efficient, creative, productive, or in some way better than habitual behavior." [behaviour], (1983, p.1362). It provides a strong sense of self-fulfilment and an accompanying sense of power.

Flow has aspects of both peak experience and peak performance; where there is intense enjoyment in working through challenges that match the skill set of the individual. Privette sums up the overlapping characteristics of the three as follows:

> Childbirth and sexual experiences are other frequently mentioned peak experiences, neither of which, in itself, is peak performance. Childbirth often is not flow; sexual activity often is.
>
> (Privette, 1983, p.1364)

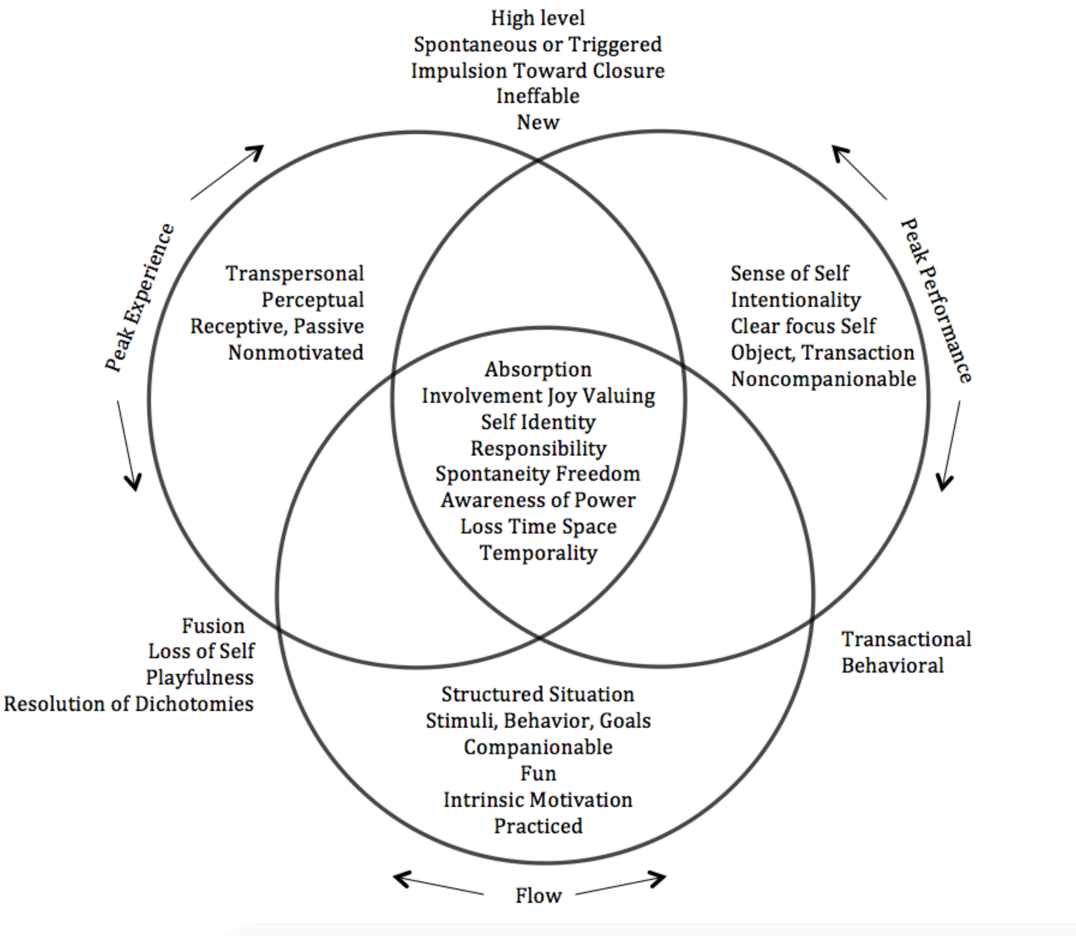


Figure 2.4 A comparison of the topologies of peak experience, peak performance, and flow, redrawn from the original in Privette, 1983, p.1366

Csíkszentmihályi developed flow theory in an attempt to explain the persistence of intrinsically motivated, autotelic behaviour, irrespective of the presence or absence of external rewards. He proposed that when an activity provides challenge at a proximal level to the individual's skill development, *id est* work that is challenging but achievable with effort, the activity becomes "intrinsically rewarding, such that often the end goal is just an excuse for the process", (Nakamura & Csikszentmihalyi, 2009, p.196); or to put it another way, "Flow is fun", (Privette, 1983, p.1364). To achieve this state, goals and feedback must be clear and immediate. Csíkszentmihályi represented the relationship between skills and challenge that support flow behaviour, where the flow channel separates anxiety from boredom, in the following diagram, (Figure 2.5).

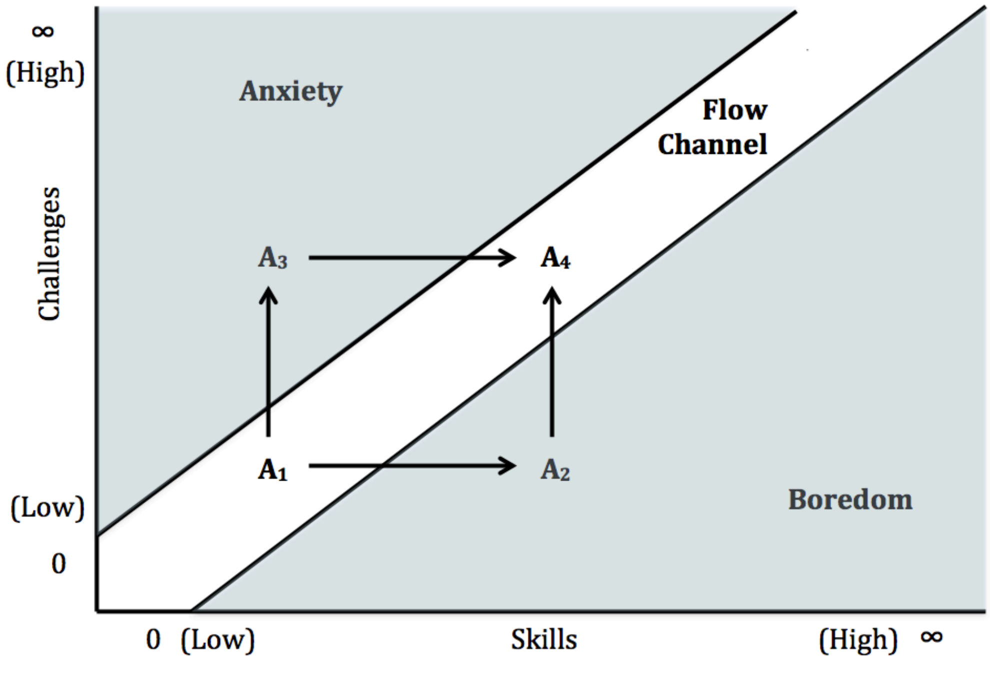


Figure 2.5 The Flow Channel, redrawn from the original in *flow*: The Psychology of Happiness, Csikszentmihalyi, 1992, p.74

An individual, whose skills improve through practice, on the same challenge over time, moves out of flow, (A_1), and into boredom, (A_2). The only way to regain flow, (A_4), is to increase the difficulty of the challenge. Alternately, if the initial challenge is too great for the skill level of the individual, (A_3), anxiety is experienced and only when skills have improved to match the challenge will flow be resumed, (A_4). This diagram correlates well with Vygotsky's concept of the zone of proximal development, (ZPD), as, to remain within the flow channel, the challenges an individual faces must be close to the skill set he has just mastered; a task too easy or too hard moves the experience, from flow, to one of boredom or anxiety. Thus flow activities should be composed of a series of increasingly difficult challenges to match skill development and maintain the individual's enjoyment.

> Activities conducive to flow are those that are *designed* to make optimal experience easier to achieve. They have rules that require the learning of skills, they set up goals, they provide feedback, they make control possible.
>
> (Csikszentmihalyi, 1992, p.72 italics in the original)

At a more immediate level, the interplay between skills and challenges can initiate further emotions, both positive and negative, (Csíkszentmihályi, 1997, 2004). Massimini, Csíkszentmihályi and Carli, (1987), developed and used an experience-sampling method to investigate the effects of altering the skills:challenge ratio. In their analysis they divided skills and challenges into categories of high, medium and low, thus generating a three by three matrix of nine states. The medium challenge/medium skill condition, described by Keller and Bless, (2008), as the "regulatory compatibility experience", where an individual's skills match the complexity of the task at hand, appears as a point at the centre of the diagram that follows, (Figure 2.6). Tasks involving high skills and high challenges have previously been identified as being conducive to flow, (Moneta & Csikszentmihalyi, 1996; Shernoff *et al.*, 2003). When an individual is challenged above and beyond the norm, then arousal ensues. This area, according to Csíkszentmihályi, (2004), is where most learning takes place. Control lies within an individual's comfort zone but is not particularly exciting, as the challenges are limited. Flow can be entered easily from both arousal and control. The highly negative state of apathy arises when tasks demand low skills and offer little challenge; here there is no opportunity for growth. Boredom and anxiety ensue when a task is either too easy or too hard; the same aversive conditions investigated by Atkinson, (1957), who studied the motivation for risk-taking behaviour.

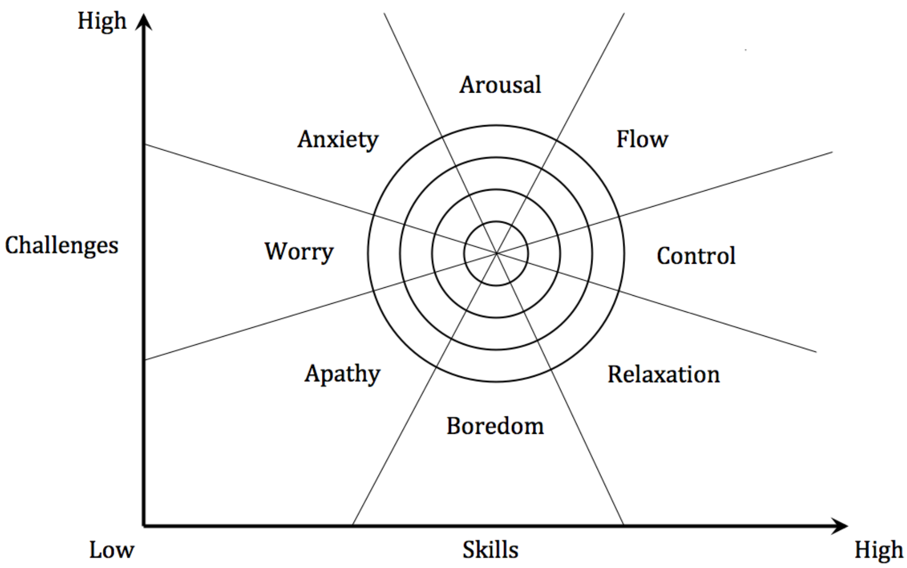


Figure 2.6 The interplay of Skills and Challenges, redrawn from the original in Finding *flow*: The Psychology of Engagement with Everyday Life, Csikszentmihalyi, 1998, p.74

The relevance of Flow to student action cycles will be further discussed in the conceptual framework that follows, (section 2.6).

2.2.11 “Conflict, Arousal, and Curiosity”

> The challenge for education, especially during the elementary and secondary years, is to introduce appropriate elements of surprise, contradiction, paradox, or doubt to induce optimal levels of conceptual conflict and novelty – not too familiar and not too remote – thereby arousing and sustaining curiosity and reaping its epistemic benefits.
>
> (Messick, 1979, p.286)

Historically, curiosity was regarded as an emotion closely related to fear, in that the two are responses to similar stimuli. This perspective was built on by Berlyne, (1960), in his seminal work, “Conflict, Arousal, and Curiosity”, in which he describes a homeostatic, curiosity drive that encourages exploratory behaviour to reduce the unpalatable sensations of under- or over-arousal, and uncertainty, to restore perceptual coherence; or to use Festinger’s, (1957), terminology, to replace dissonance with consonance.

In his writings, Berlyne identified novelty, uncertainty, conflict and complexity as key external stimuli and grouped them together as collative variables, (1954, 1960). He separated curiosity into perceptual curiosity, an appetite for increased perception of a stimulus characterized by exploratory behaviour, and epistemic curiosity, the search for knowledge; though he considered that the two might be related. Lowenstein, (1994), regards perceptual curiosity as a misnomer and proposes a better label to be attention, and states that exploratory responses "are not necessarily intrinsically motivated, are unemotional in character, and lack the drive properties associated with a cognitive appetite" (p.77). Voluntary attention though, is a higher cognitive function where effort must be consciously expended.

Berlyne further divided epistemic curiosity into specific curiosity, the pursuit of information to satisfy the gap in one's knowledge, and diverse curiosity, a sensation-seeking response for stimulation to fend off boredom, reiterating, to some extent, Fowler's, (1965), view that boredom, rather than curiosity, should be regarded as the stimulus. He also considered curiosity as either a state or trait, with the former being an interest in a particular situation and the latter, a general ability or propensity.

However curiosity as a stable trait, was discounted by Coie, (1974), after conducting trials with four curiosity-inducing tasks on children, (n=120), between the ages of six and nine. She determined that children might be hugely curious in some circumstances while not in others. This result reflects more recent findings that some students are intrinsically motivated in some subjects but extrinsic in others, and that some are either universally intrinsic or extrinsic in their motivation, (Harter 1981, Harter & Jackson, 1992).

The separate approaches of knowledge deficit and sensation were combined by Litman and Jimerson, (2004), in their interest-deprivation model. The analogy that feelings of hunger can arise from the aroma of food, or an empty belly, and that both can be pleasurably satisfied by eating, (Litman, 2005), were used to illustrate this interplay. As Lowenstein puts it:

> The key to understanding curiosity seeking lies in recognizing that the process of satisfying curiosity is itself pleasurable.
>
> (Lowenstein, 1994, p.90)

Litman later expanded this into his integrative interest-deprivation/ wanting-liking model of curiosity by introducing discoveries in the field of neurobiology on the chemical involvement of dopamine and opioids in the desires of wanting, and the activity of liking respectively, (2005).

In relation to teaching and learning, challenge, control, curiosity and more recently fantasy, the vicariousness of virtual reality, (Lepper *et al*. 1997), are regarded as instrumental in fostering and maintaining intrinsic motivation. Challenge and control are similar in that they may be considered as means to demonstrate, or authenticate, competence, while curiosity and fantasy share the desire to close a knowledge gap or avoid the tedium of the status quo. It is human nature to be curious, as Pink states:

> Have you ever seen a six-month old or a one-year-old who's *not* curious and self-directed? I Haven't. That's how we are out of the box. If, at age fourteen or forty-three, we're passive and inert, that's not because it's our nature. It's because something flipped our default setting.
>
> (2009, p.89 italics in the original)

Most curious to the individual, according to Day, (1982), will be situations that are moderately familiar, as anything too dissimilar from that which has so far been experienced is unlikely to generate symbolic response-tendencies of sufficient magnitude to generate much conflict. The commonplace is unlikely to foster curiosity either, as familiarity is likely to have largely removed the potential for conflict, making the outcome an expected one. Day represented the region most likely to generate cognitive conflict, and where learning takes place, as the "zone of curiosity" (Figure 2.7).

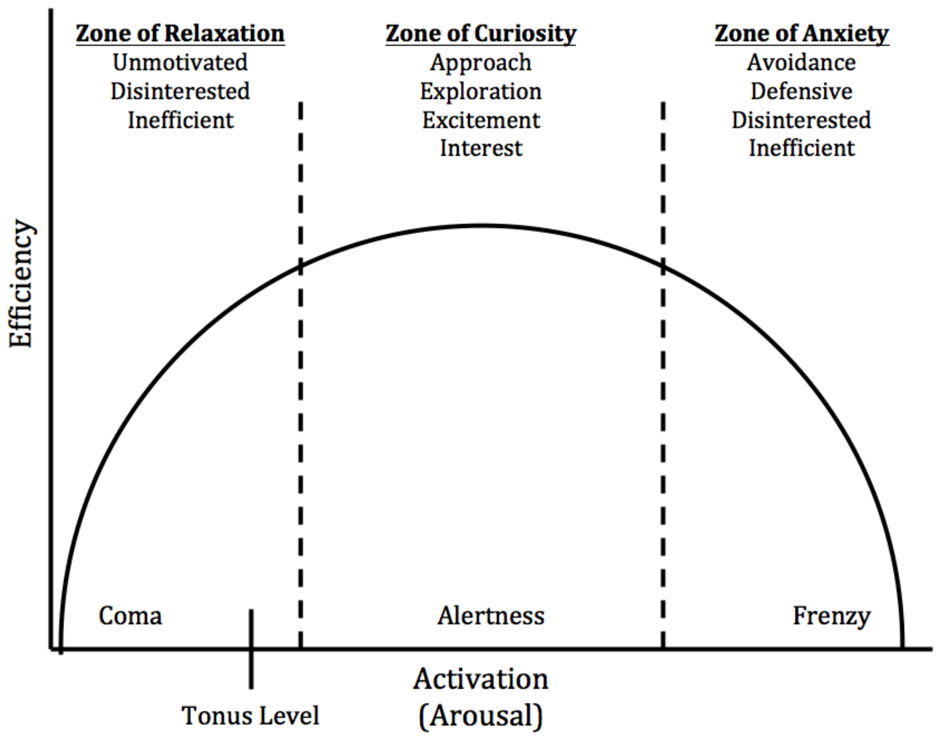


Figure 2.7 The effects on behaviour and affect of changes in activation level in an organism, redrawn from the original in Curiosity and the Interested Explorer by Day, 1982, p.20

Vygotsky might have argued that Day's zone of curiosity overlaps with his zone of proximal development, (ZPD). That is to say, a child is selective about what is perceived to be interesting, rather than being a passive recipient of the varied stimuli of its environment, and that this changes with the age period of the child. What may captivate a child in its infancy is likely to be less alluring at puberty.

> When I was a child, I spoke as a child, I understood as a child, I thought as a child: but when I became a man, I put away childish things.
>
> (1 Corinthians 13:11(KJV))

In moving from one age of development to the next, the dissonance between the established capabilities of the individual and the needs, desires and possibilities that they are alert to was described by Vygotsky as a new formation, (neoformation). He argued that being aware of the constraints of childhood developmental stages would cause a drive to actively explore opportunities for emancipation through stretching one's abilities. There is disinterest in the characteristics of the previous developmental stage, as there is with anything too far in advance of the current stage.

> All the major new mental functions that actively participate in school instruction are associated with the important new formations of this age, that is, with conscious awareness and volition. These are the features that distinguish all higher mental functions that develop during this period.
>
> (Vygotsky 1934/1987, p.213)

Piaget might have argued, like Day, that when a child has made sense of most of the experiences he or she is aware of, and has assimilated these within schemas, it is the moderately familiar experiences, not yet accommodated, that are the driving force for the child to make sense of the world, through the process of equilibration. Anything too familiar or too far beyond the comprehension of the individual is unlikely to arouse curiosity.

> The more the schemata are differentiated, the smaller the gap between the new and the familiar becomes, so that novelty, instead of constituting an annoyance avoided by the subject, becomes a problem and invites searching.
>
> (Piaget 1954, p.354)

Day's zone of curiosity would also be recognised by Csíkszentmihályi as that which delineates the boundaries of the flow channel between boredom, arousal and anxiety.

Whilst students are concentrating on establishing an initial degree of familiarity with a topic, Loewenstein asserts that the main focus is on the material that is present, but that as information is acquired, a shift takes place to a focus on what is not known; the gap in knowledge. He describes this as "the genius of curiosity", (1994, p.89).

As curiosity appears to be integral to intrinsic motivation it might be prudent to pause and consider for a moment why Lepper *et al*. (1997), question the reason for what they describe as "motivational deficit", (p.23), in children schooled in a *traditional* classroom environment, and why Einstein is purported to have suggested that it is a miracle that curiosity survives formal education.

There is support for the Lepper *et al*. assertion from Harter's analysis of over three thousand responses to her "Scale of Intrinsic versus Extrinsic Orientation in the Classroom" questionnaire, (Harter, 1981a), (Figure 2.8), where she concluded that:

> our school systems are gradually stifling children's intrinsic interest in school learning, specifically with regard to challenge, curiosity, and independent mastery.'
>
> (Harter, 1981b, p.309-310)

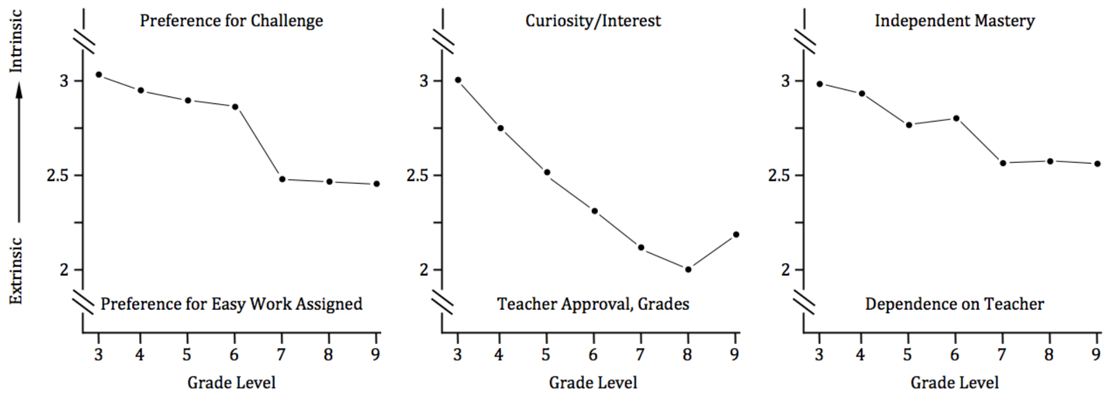


Figure 2.8 The mean score by grade level for each subscale, redrawn from the original in A New Self-Report Scale of Intrinsic Versus Extrinsic Orientation in the Classroom by Harter, 1981b, p.307

Similar research by Engelhard and Monsaas, (1988), using a different instrument, also showed a decline in curiosity as measured with eight, ten and twelve-year-old students as they move towards Vygotsky's "crisis at age thirteen", (section 2.3.6), characterised by a:

> decrease in success, decline in capacity for work, lack of harmony in the internal structure of personality, contraction and dying off of systems of previously established interests, and the negative, protesting character of behaviour
>
> (Vygotsky, 1998 p.193)

In contrast, Coie's, (1974), research showed no evidence that children's inherent curiosity was diminished by their educational experiences. More recently though, Crow, (2010), found that only nine out of the 100 ten and eleven year old students she surveyed were intrinsically curious.

The increased cognitive demand of curricula for older children has been regarded as one of the causal factors in a decline in intrinsic motivation, (Loewenstein, 1994). Though Lepper *at al*. (1997), have suggested that older students may just be more attuned to the extrinsic value of success and failure in the summative assessments that affect their future, and consequently trade off curiosity for curriculum content.

2.2.12 Examinations – Diploma disease

> Schools used to be for educating people, for developing minds and characters. Today, as jobs depend more and more on certificates, degrees and diplomas, aims and motives are changing. Schooling has become more and more a ritualized process of qualification-earning.
>
> (Dore, 1997a, back-cover)

In 1976, Dore published his, at the time, controversial book entitled "The Diploma Disease" in which he highlighted concerns about qualification inflation; where the entry requirement for a particular job over the course of time requires ever increasing levels of certification. He stated that a consequence of this was that students were staying on in schools longer than either their own personal development, or the acquisition of useful occupational skills, could justify.

In essence, examination certification delivers a necessary employment currency that has decreasing value year on year. To support this he cited the Mason report, (1995), that showed that university graduates were accepting employment in positions, with no prospect of career advancement, that would have traditionally been filled by school leavers.

Furthermore, Dore, (1997a, 1997b, 1997c), stated that the concomitant effect of increasing numbers of third level entrants, (e.g. the rise from fifteen percent to thirty percent in Britain during the course of the 1980s), is a reduction in university standards. Only twenty years later on, and for comparison, the number of Irish leaving certificate students proceeding to further study had risen from twenty percent to over sixty percent, (in just one generation), and was predicted to rise by a further thirty percent in the next decade, (Bielenberg, 2015).

> University enrolment is growing faster even than demand for that ultimate consumer good, the car. The hunger for degrees is understandable: these days they are a

> requirement for a decent job and an entry ticket to the middle class.
>
> ("The Economist", 2015)

Dore referred to this credentialism, as a "bread-and-butter, certificate-seeking lifelessly instrumental motive for learning", (1980, p.60), with the sole purpose of getting a job and compared it, very unfavourably, to both learning for its own sake and learning to up-skill.

In a clarification of the issue, Little, (1997), points out that diploma disease is a pathology of societies rather than the individual, as it is socially legitimate for individuals to pursue career-enhancing, rote-learning derived exam success in the hope of improving their life-chances.

In the late 1980s, the Student Learning Orientations Group, (SLOG), published the report of a six-country study into students' motivation for learning, with the diploma disease thesis as its basis, (Institute of Development Studies, 1987). Their results were unsurprisingly varied, as they came from industrialized and industrializing countries, but showed that in England, at that time, the goal of successful examination performance was the most significant motivational factor. They agreed that:

> Educational institutions become places where people prepare to take examinations and be assessed rather than places of learning.
>
> (Dore, 1970, p.1)

Twenty years later in Ireland the focus on 'surface learning', where only examined knowledge and skills are taught, assessed and valued, was still very much alive according to Stobart, who cited the example of Ruth Borland, who gained maximum points in the Leaving Certificate in 2005 by 'working the system'. In her own words, she did well by:

> Learning the formula for each exam and practicing it endlessly. I got an A1 in English because I knew exactly what was required in each question. I learned off the sample answers provided by the examiners and knew how much information was required and in what format in every section of the paper. That's how you do well in these examinations … There's no point in knowing about stuff that is not going to come up in the exams. I was always frustrated by teachers who would say 'You don't need to know this for the exams but I'll tell you anyway'. I wanted my A1 – what's the point of learning material that won't come up in the exams?
>
> (Stobart, 2008, p. 9-10)

The final sentence very clearly resonates with Dore's categorization of learning to get a job. It cannot be disputed that qualifications assist social mobility in a class-system meritocracy but it would be of significant concern if the primary motivation to learn were now solely focused on maximizing future employment prospects.

Ireland endures a grinds culture, a colloquialism to indicate paid-for private tuition, or "shadow education" as Smyth, (2009), calls it. In her meta-analysis of data from the 2004 School Leavers Survey, (SLS), and the 1994 Schools' Database, both conducted by the Economic and Social Research Institute, (ESRI), she found that "Participation in private tuition is disproportionately concentrated among students from middle-class families", (p.1), who tend to already be high academic achievers. "Middle-class" students, whom she said were at high risk of social demotion by not staying on in education, attended, while "working-class" students, to whom the cost-benefit may not have been a relevant factor, did not. After taking into consideration the decidedly selective nature of the students involved, Smyth claimed to see no observable benefits in terms of leaving certificate examination performance from students taking grinds; even though 45% of the 2003 cohort partook. That is to say, these students were already performing above the level of their peers, and therefore the grinds added little value to grades; but may have provided a sense of security much like a 'comfort blanket'. This class-divide continued after the examinations with 84% of school leavers from higher professional backgrounds attending third level courses in comparison to only 38% from unskilled manual backgrounds. In rationalizing this difference Smyth proposed that parents with higher levels of education, the professionals, are more likely to be aware of how the system works and to be better able to assist their offspring.

2.2.13 ROSE – Listening to the 'student voice'

The acronym ROSE refers to an international research project into students' views on the Relevance of Science Education that collected data in Ireland in 2003 through a battery of 217 questions with answer options on a four-point Likert-scale, (Matthews, 2007). The questionnaire was given to students with an average age of 15.5, in transition year or fifth year; meaning they had completed their junior certificate science studies. There were six themes to the survey: “What I want to learn about”, “My future job”, “Me and the environmental challenges”, “My opinions about science and technology”, “My out-of-school experiences” and “Myself as a scientist”. Of the one hundred and eight questions that focused on content, a relatively small number, around 11%, touched on material that the students would have engaged with as part of their studies.

The results made interesting reading in that:

> A slight majority of students have more positive than negative responses to Junior Certificate Science. In the main they enjoy the subject.
>
> (Matthews, 2007, p.4)

Some of the lowest scoring items were for topics that formed a significant component of the junior certificate, such as atomic structure, plant biology and electricity. Whether this reported dislike reflected the content, or the manner in which it was delivered, cannot be determined from the data. It may well be that the topics students selected as most interesting, namely “health, sex, genetics, natural disasters and the origin of life, space and the universe”, (p.4), would have scored less highly if they had been major curriculum components. Gender bias was apparent in the results with girls showing more interest in “eating disorders, babies and cosmetics”, (p.4), and boys preferring “explosive chemicals and nuclear weapons”, (p.4). When they were asked about future career options:

> The great majority of students do not want 'to become a scientist' or 'to get a job in technology' (55% of students chose the extreme 'disagree' option for the former statement and 44% for the latter statement.)
>
> (Ibid., p.5)

Norwegian students, who answered the survey, in a preliminary study, showed a similar disinterest.

> When asked about their interest in various professions, the highest scores were given to film production, web design, architecture and journalism, while agronomy and science teaching were at the bottom
>
> (Schreiner & Sjøberg, 2004, p.44)

Two criticisms that have been raised against ROSE are its claim to listen to the student voice, when the questions were prescribed and did not allow for free student input, and that it only covered content and not pedagogy. Both of these comments were addressed in a similar study conducted in England, by students, on the structure and delivery of the English General Certificate of Secondary Education, (GCSE), in science, (Murray & Reiss, 2005). This developed into the Student Review of the Science Curriculum, (SRSC), out of a proposal by the London Science Museum to do something to celebrate Science Year, (2001-2002). It took the form of a web-based survey, designed and compiled by over three hundred and fifty students between the ages of sixteen and nineteen and targeted Key Stage 4, (KS4), students, between the ages of fourteen and sixteen. Analysis of the fifteen hundred responses provided a number of key findings in regard to curriculum content, effective ways of learning, attitudes to science, and modes of assessment.

When students were asked for an opinion about the number of facts that they were expected to memorize, the emphasis on rote learning and exam pressure appeared prominently in answers, and in quotes, (Ibid., p.3), such as:

> There are too many. To get a good grade you do not have to be a good scientist – just have a good memory,

> I think the GCSE is not geared to rewarding those who can understand and apply scientific knowledge but just to those who are able to remember the most facts

and:

> Far too many irrelevant facts that I have now forgotten, in fact I forgot them about a week later, need to focus more on applying facts to situations so that they will be useful in real life and for the coming years.

Eighty-five percent of students described that they felt that what they learned was examination led.

Later in the survey, students were asked to select their three most useful and effective methods of learning and their three most enjoyable from a list of eleven possibilities. The results of this are shown in the table, (Table 2.1).

Table 2.1 Responses to questions on how effective and enjoyable students found different ways of learning (n= 1450), redrawn from the original in The Student Review of the Science Curriculum by Murray & Reiss, 2005, p.4

Ways of learning	Useful and effective (%)	Enjoyable (%)
Taking notes from the teacher	45	15
Looking at videos	27	75
Reading the textbooks	17	18
Taking my own notes from books etc.	24	13
Copying notes from the board	23	17
Doing a science investigation	32	50
Making a science presentation in class	17	43
Researching science on the Internet	8	44
Going on a science trip or excursion	30	85
Doing a science experiment in class	38	71
Having a discussion/debate in class	48	64

Students regarded the three most enjoyable teaching and learning methods as science trips and excursions, watching videos and conducting experiments and the three most effective teaching methods as class discussions or debates, taking teacher directed notes and doing experiments.

2.2.14 In conclusion

This section on motivation and rewards highlighted the important influences of intrigue, fulfilment, and conformity and their effects on task engagement.

The desire to satisfy curiosity, or alleviate boredom, was described as an intrinsically motivational, childhood default-setting that might be flipped by incompatible educational experiences; a view that was supported by listening to the students' voice, where their perceptions of a fact laden, largely irrelevant, examination driven curriculum were indicated.

Feel-good factor sensations of enjoyment, as a driving force for engagement, were encountered in the concepts of, peak experience, peak performance and flow, with the knock-on effect of learned industriousness. The idea that fulfilment through active involvement with tasks at a proximal level of skill development builds on curiosity and leads to a mastery learning approach was discussed.

Conformity was examined through diploma disease as an increasingly dominant driving force to accede to an extrinsic acclamation of suitability for employment; where "learning to get a job" has higher currency than learning for its own sake.

The specific mindset and the powerful influences of feedback on the learner were mentioned within the context of the opposing forces of intrinsic and extrinsic motivation and in conjunction with an evaluation of the effectiveness, or not, of various reward tokens and strategies. Perceptions of empowerment, of being in autonomous control of one's own destiny, and confidence in one's own abilities, were tied to the wider community in self-determination theory and its corollaries.

Overarching all of these discussions and acting as a framework for their development stands Maslow's Hierarchy of needs.

2.3.1 An Introduction to Cognitive Development

This section of the literature review begins with an exposition of Piaget's theory of cognitive development, as it provides a valuable overview of the various levels of thinking to be encountered within a population of children as they progress through the educational system. The ages of transition from the use of 'primitive' to 'advanced' mental processes are then discussed and evidence provided that neither the development across all domains of cognition, nor the process as a whole, appears as universal as Piaget described. Methods for assessing cognitive development through the use of reasoning tasks are then discussed and evidence of a lack of readiness for meaningful engagement with university courses, and an up to 12 year age gap in thinking patterns within secondary school classrooms, presented. A description of a programme that attempts to produce Cognitive Acceleration through Science Education, (CASE), is outlined, with accompanying data to evaluate its reported effects. Then the process of cognitive development is examined from a neurological viewpoint and related to gender and the Piagetian stages. Finally, in the conclusion to the section, the relevance of the presented material to the framework for the student action cycles, (SACs), is mentioned.

2.3.2 Piaget’s Theory of Cognitive Development

It was in 1920, while working in the Binet Laboratory at the Sorbonne, that Piaget’s interest in cognitive development was first piqued. He had been employed to standardize Burt’s reasoning tasks for French students and became fascinated with the differences in the quality of responses from children and adults when asked questions that required logical thought.

After years of study, involving his own children, those of his friends, and schoolchildren from Geneva, he came to refute earlier conceptions that the young are merely less competent thinkers, and instead proposed that the way children process information is radically different from how this is performed by adults. He regarded biological maturation as a precursor to cognitive development; in addition to the interplay between a leaner and their environment.

Piaget’s theory of cognitive development, or ‘genetic epistemology’, (1954), as he referred to it, delineates into four stages of competence that all children pass through sequentially on their route to adult thinking. Within each stage the child becomes aware of, and is able to make increasing sense of, their environment. This is done by assimilating new information into pre-existing mental schemas, or by adapting these schemas to accommodate new information.

In the first of the four, the sensorimotor stage, the infant moves from the involuntary reflex actions of the early months, such as suckling and grasping, to the development of symbolic thought, the idea of object permanence and the ability to speak.

From about the age of two until seven, children operate within the pre-operational stage, which is divided into the symbolic function, and intuitive thought sub-stages. Younger children, in the symbolic function sub-stage employ precausal thinking and also exhibit egocentrism; the inability to accept that different viewpoints might exist.
The three main characteristics of precausal thinking are animism, artificialism and transductive reasoning. Children exhibiting animism ascribe lifelike qualities to inanimate objects while artificialism is the belief that environmental factors are a direct result of human influence. Transductive reasoning pre-empts inductive and deductive reasoning and is a state where relationships between variables are made but where an adult might not see any valid connection.

Children in the intuitive thought sub-stage exhibit centration, a mental process where one component of a situation is regarded to the complete exclusion of all others. Piaget demonstrated centration by pouring fixed volumes of liquid into different containers and showed that children were incapable of understanding the ideas of conservation and reversibility. Furthermore, children are unable to apply class inclusion, where one category may contain several subcategories, or transitive inference, namely that if A is greater than B and B is greater than C, A is also greater than C.

The first of the stages that should be relevant to students entering secondary education is the concrete operational stage, which according to Piaget, is normally completed by the age of eleven. The use of concrete in the stage title distinguishes the type of thought processes of the child from both an abstract, hypothetical style of thinking that has not yet developed, and inductive reasoning, which is firmly based on tangible objects and events. Although a child may be able to draw inferences from observations, true deductive reasoning, relying on generalization, is typically not yet possible. In addition, it is in this stage that the egocentrism of earlier stages is replaced by a realization that others also have opinions, which may be valid, even if not necessarily correct. Children are able to work logically with a limited number of variables and are usually fluent in the mathematical skills of addition and subtraction. Hierarchical classification becomes possible as does seriation, the ability to sort objects based on size, shape or other characteristics, and transitivity, that is being able to mentally arrange objects in order. The centration exhibited in the previous cognitive stage is gone and with its demise the concepts of conservation, in relation to mass or volume, and reversibility are developed.

It was Piaget's opinion that his final formal operational stage would be completed by all during adolescence. Individuals in this stage develop the ability to use abstract concepts and symbols logically and are capable of hypothetico-deductive reasoning. Problem solving moves from the trial-and-error approach of earlier stages to one that is characterized by logic and method.

In setting out these stages Piaget clearly identified intellectual processes that need to be at least developing before productive engagement with certain curriculum material can be achieved.

2.3.3 Ages of transition though Piaget's stages and the SRTs

Piaget was very much aware that the ages of transition from one stage to the next are influenced by the social environment of the child but observed what he described as "astonishing convergence", in that children from the same social environment progressed at around the same age. He also noted that although ages might differ, the sequence of stages mastered was always the same; citing complementary experiments in comparative psychology conducted in Africa and Asia to support this. Indeed, when discussing ages of transfer in the documentary he produced in collaboration with Goretta he states:

> among children in the city of Tehran in Iran the ages are the same as for school children in Geneva. But the same questions asked of illiterate Iranian children in the mountains give answers which are three years later. But the stages are the same.
>
> (Piaget, 1997)

He was also aware that children might simultaneously exhibit characteristics of more than one stage; an observation that is more in tune with Bruner and Vygotsky's proposal that cognitive development is a continuous process. Piaget also reflected that language is an important mediator in the process of cognitive development but never formalized his ideas to quite the same extent as Vygotsky did.

Some researchers have proposed that Piaget underestimated the abilities of children as the assessments he used were either confusing or the tasks too difficult to understand. For example, when Hughes, (1975), replaced Piaget's 'Three Mountain Task' with the 'Policeman Doll Study' he found that children had, in large, progressed from egocentric thinking by the age of four; three years earlier than Piaget's research had suggested. This finding resonates with Piaget's comments about Iranian children.

Dasen, who studied under Piaget, affirms that the assumption of universality in the hierarchical order of stages is demonstrable although the relative rate of cognitive development in different domains is strongly influenced by cultural and environmental factors. In the first of several cross-cultural studies he investigated the cognitive development of Australian Aboriginal schoolchildren, between the ages of eight and fourteen, by testing their performances in two domains of concrete operational thinking; namely quantification and spatial reasoning. Whereas Genevan children had been shown to master conservation between the ages of five and seven, (tested through the liquids in different containers task), Dasen discovered that the same level of mastery developed in Aboriginal children between ages ten and thirteen; marking a much later transition out of the preoperational stage. He also noted, "a fairly large proportion of adolescents and adults also gave non-conservation answers" (Dasen, 1994, p.147). On spatial reasoning however, the Aborigines demonstrated mastery at a much earlier age than Genevan children. Dasen concluded that if progress in different domains is non-uniform then it is impossible to attribute a single cognitive developmental level to any individual. He ascribed different rates of progression in different domains to the value placed on each domain in a cultural context; that is to say, for nomadic people the ability to locate oneself in one's environment, the use of spatial reasoning, is more important for survival when compared to conservation, but conversely in settled populations the amount of goods possessed may be of more importance than determining location.

The complexity of various aspects of the science reasoning tasks, (SRTs), discussed next in this literature review, and used with students in this study, coupled with the current Irish cultural context may have implications with regard to the fitness for purpose of the SRTs. Indeed, with the removal of sand and water play tables from national schools, for example, it is likely that students may not have had sufficient experience of the concept of conservation to meaningfully engage with tasks relating to this and therefore, like Piaget's Iranians and Dasen's Aborigines, might underperform in quantification.

While working with the Concepts in Secondary Mathematics and Science Programme, (CSMS), in 1974, Wylam and Shayer developed a series of science reasoning tasks, (SRTs), based on the Piagetian model of cognitive development just described. The CSMS team discounted the use of standard intelligence quotient, (IQ), tests as an instrument for determining cognitive development, stating that the results of these are age dependent, and do not directly measure development *per se* but rather provide a comparison of the development within an age group. They also stated that

IQ tests provide little information on the quality of thinking, which is however data they felt could be provided by the SRTs, thus reiterating Piaget's earlier concern that quantitative result from SRTs are less valuable than the quality of the responses, (Shayer & Adey, 1981).

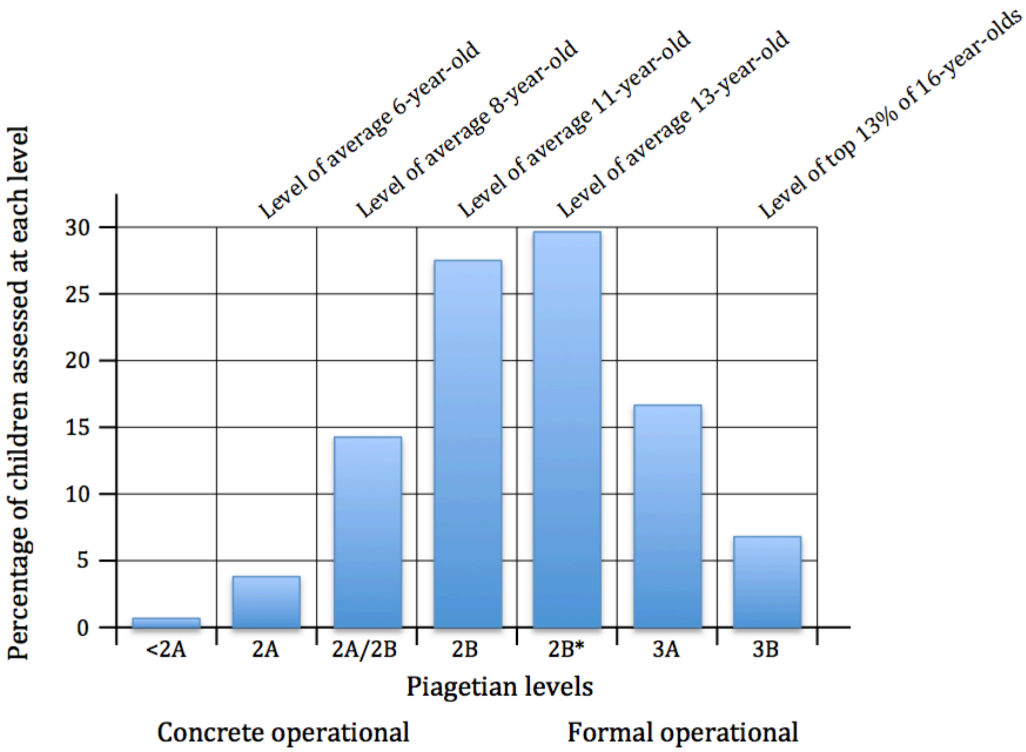


Figure 2.9 1974/5 CSMS survey of 14,000 children between the ages of 10 and 16: data for 14-year-olds, redrawn from Shayer, 2002, p.183

The SRTs developed were used, in England and Wales in the academic years 1974/75 and 1975/76, by Shayer, Küchemann and Wylam to survey the levels of fourteen thousand children between the ages of nine and sixteen. What they discovered was that the spread of abilities with regard to reasoning was much wider than had been previously thought, (Figure 2.9).

Within a typical class, of twelve year old children, they reported that some would be found to be reasoning as an average eight year old while others would be thinking in a similar manner to the most able sixteen year old; an eight year gap.

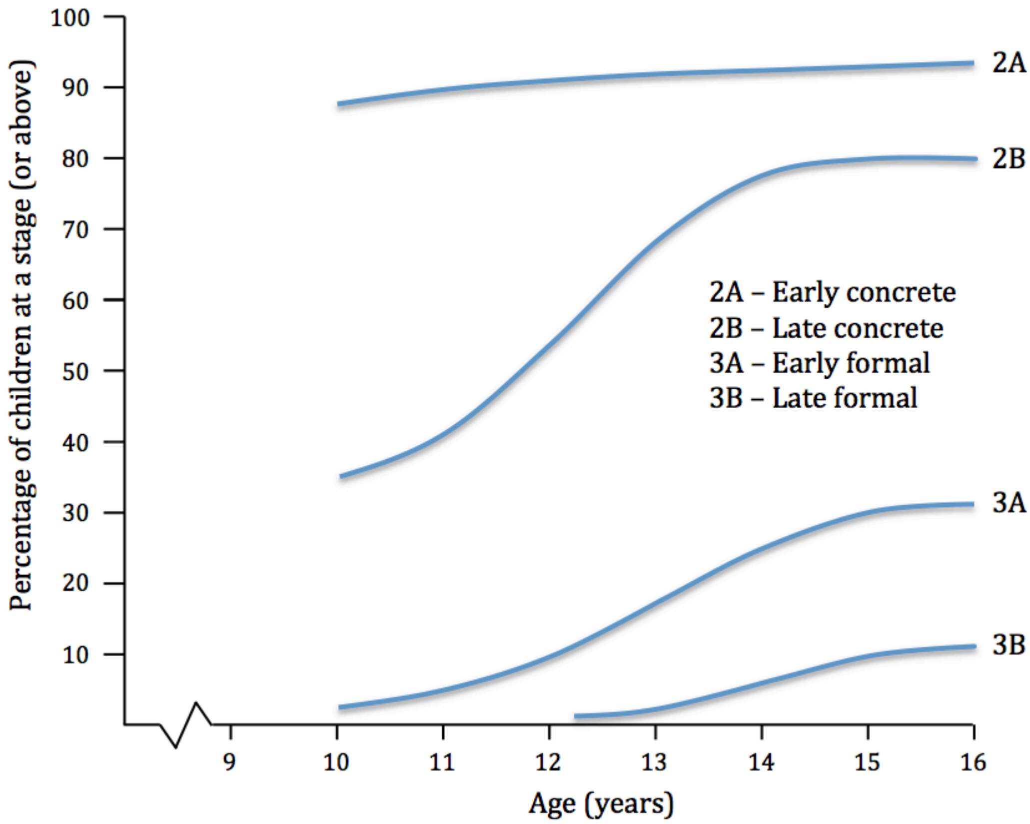


Figure 2.10 The proportion of children at different Piagetian stages in a representative British child population redrawn from Shayer and Adey, 1981, p.9

Their results also indicated that only around 30% of fourteen to fifteen year-old students had made the transition to formal operational thinking, and this percentage did not rise in the subsequent year. This is in stark contrast to Piaget's claim that the population as a whole, from eleven years onward, acquires formal operational thought. But then, as Dasen reminds us, Piaget's research was conducted in highly selective schools in Geneva, catering to only about 5% of the population. Dasen commented that, “It needed studies with other samples to discover that formal reasoning is not as pervasive as initially thought.” (Dasen, 1994, p.149), (Figure 2.10).

Shayer later claimed that the year 2000 Key Stage 3, (KS3), Standard Assessment Tasks, (SATs), data for mathematics showed that the eight year gap in the 1974/75 SRT results had extended to twelve years, by extrapolation; although the validity of this inference might be questioned, when considering the very different nature of the two tests.

When Shayer revisited the work on the SRTs, nearly thirty years after the original study, he reported a general decline in performance on the “*Volume and Heaviness”* science reasoning task such that the peak in distribution had moved from the mature concrete 2B* level to early concrete 2A/2B, (Shayer, Ginsburg & Coe, 2007, p.31), (n=10,023). This decline in science reasoning ability was also observed when students were assessed on the tasks “*Equilibrium in the Balance”* and “*the Pendulum”*, (Shayer & Ginsburg, 2009), such that the pair concluded:

> It seems that there has been a change either in general societal pressures on the individual or in the style of teaching in schools – or both – favouring a lower level of processing of reality.
>
> (Shayer & Ginsburg, 2009, p.409)

Within an Irish context, McCormack's, (2009), doctoral thesis presents an analysis of the cognitive level profile of students in a number of schools in and around Dublin. What she reports is that less than 10% of students entering second level education were capable of formal operational thought, (Figure 2.11). This study was extended to the analysis of first year university students on a number of different science courses, (McCormack, Finlayson & McCloughlin, 2009), where she discovered that while nearly 70% of students were capable of formal operational thought, less than 10% were capable of the late formal thinking, (Figure 2.12), which would be required for meaningful engagement with course materials; the remaining 32% of students were still in the concrete operational stage that, according to Piaget, they should have left behind around the age of eleven, (Figure 2.10).

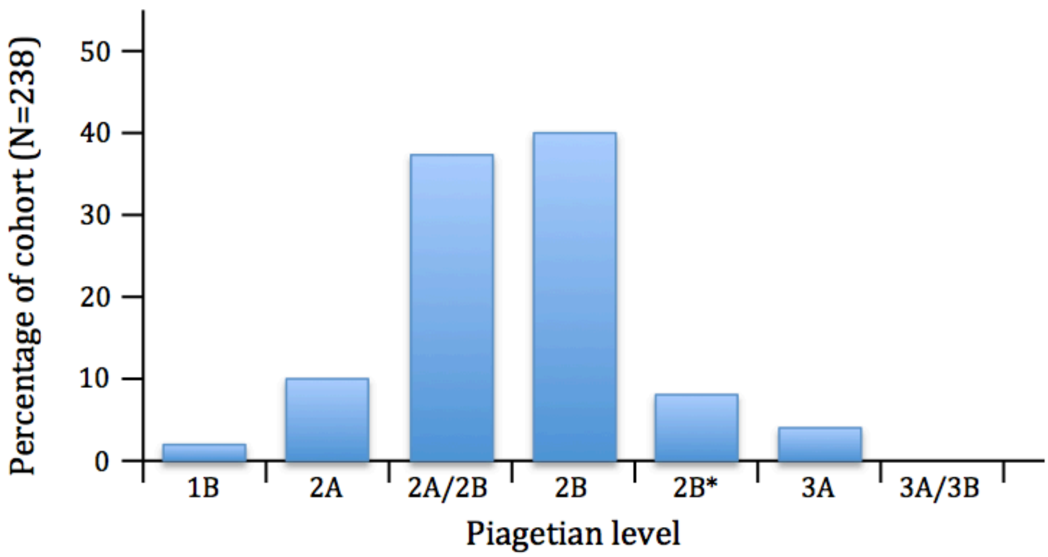


Figure 2.11 Piagetian levels for 12-year-olds on science reasoning task II, redrawn from McCormack, 2009a, p.164, Figure 2.27

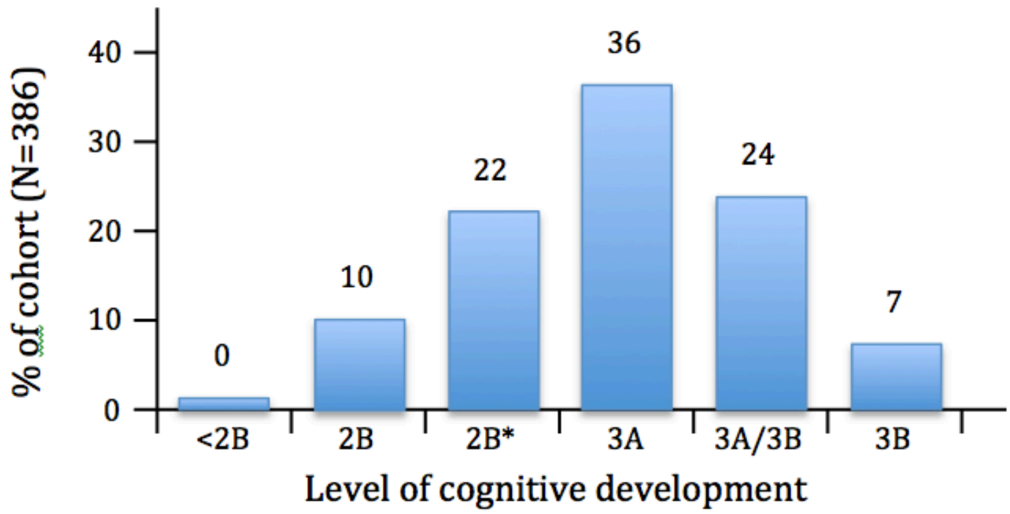


Figure 2.12 Piagetian levels for 1st year university science students (Average age 18.8 years), redrawn from McCormack, 2009b, p.6, Figure 3

The CSMS programme also produced two complementary taxonomies based on Piaget's writings that allow for a systematic analysis of curricula in terms of cognitive demand. Their ideal was that it should be possible, by combining student testing and curriculum analysis, to determine the upper limit of content accessibility for a student, or groups of students, and hence tailor the content to the learner.

2.3.4 Cognitive Acceleration and CASE

Shayer and Adey's matching of curricular demands to students' levels of cognition, identified through the use of science reasoning tasks, (SRTs), had highlighted the issue that in an average mixed ability classroom there is typically a broad spectrum of cognitive ability. This led the pair to consider whether there were any methods that could be employed to enhance, or accelerate, cognitive development. They were aware of research conducted in America by Kuhn and Angelev, (1976, p.704), who had concluded “that exercise of the cognitive functions in question is sufficient to promote their development” and of similar work from Australia by Rosenthal, but initially, due to the lack of definite evidence, remained unconvinced that anything other than a cognitive level matching policy would generate substantial improvements for students, (Shayer & Adey, 1981). Less than ten years later they had what they regarded as the definitive proof they had been looking for from the results of their *Thinking Science* programme, developed by the Cognitive Acceleration through Science Education (CASE) project with Yates at Kings College London, (Adey, Shayer & Yates, 2001).

Thinking Science is an intervention program for students between the ages of eleven and fourteen that is based on the genetic epistemology of Piaget, but also incorporating Vygotsky’s learning theories, to form an amalgam designed to accelerate the development of higher order thinking. The program is built around five principles, or pillars, namely, concrete preparation, cognitive conflict, social construction, metacognition and bridging; the first and last provide context while the middle three are core to the program, (Adey & Shayer, 2009).

Cognitive conflict arises when observations are found to be contrary to preconceptions. Following Piaget’s theory, the individual is now faced with the task of equilibration to accommodate the new information that cannot easily be assimilated; that is to say the student has to actively construct knowledge rather than passively absorb information. If this conflict is provided within Vygotsky's zone of proximal development, (ZPD), then the process of assimilation is unlikely either to be too hard, or to easy to accomplish and the individual can be described as "working in the construction zone", (Newman, Griffin & Cole, 1989).

Vygotsky identified the importance of social interaction, namely social construction in cognitive development, where talking and listening to others' ideas and then reconstructing them allows understanding to be developed first within a social context and then subsequently to be internalized by the individual, (Vygotsky, 1978). As he wrote in *Thought and Language*, "Experience teaches us that thought does not express itself in words, but rather realizes itself in them", (Vygotsky, 1986, p.251). Adey argues that working in the ZPD with the guidance of more able peers provides for a cognitively stimulating experience that promotes development, (Adey, 1999, p.6), a view echoed by Harrison, who affirms that "the quiet classroom is not the environment for learning to take place", (2006, p.75).

The third core pillar of CASE, metacognition, is the process of reflecting on one's own thinking strategies. The CASE team argued that only by encouraging the individual to consciously articulate his or her own thinking processes can cognitive development be promoted, (Shayer & Adey, 1981).

Concrete preparation is essentially the process of setting an appropriate context for the planned learning such that it allows students to engage with the new content in a meaningful manner. As Ausubel states, meaningful learning only takes place when, “new symbolically expressed ideas (the learning task) are related in a nonarbitrary, and nonverbatim fashion, to what the learner already knows”, (2000, p.67).

The fifth pillar, bridging, is a process of extending context specific reasoning into broader everyday experience so that the student can use newly developed thinking skills to solve a wider range of problems.

In their later review of CASE, Adey and Shayer, (2002, p.4), introduced a sixth pillar, namely schema theory, which replaced the term ‘reasoning patterns’ used in the original *Thinking Science* materials. These reasoning patterns, the control and exclusion or irrelevant variables, classification, ratio and proportionality, inverse proportionality and equilibrium, probability and correlation and the use of abstract models to explain and predict, are parallels of the traditional Piaget and Inhelder, (1958), schemas involved in formal operational thinking.

2.3.5 How reliable are the effects of a CA intervention program

The first *Thinking Science* experiments, conducted by the original members of the CASE team over a three year period, (1984-87), involved a relatively small number of students, eighty-three boys and seventy-four girls, but provided enough empirical data to warrant extending the research to a wider audience.

Adey and Shayer recall that the experimental/control pre-test, post-test and delayed post-test design showed immediate and long term results, as well as far transfer effects from General Certificate of Secondary Education, (GCSE), science to mathematics and English; where improvements were recorded as being in the order of between a half and one full grade across the board, (2002). This improvement was assessed by the method of residualized gains scoring, where a relationship was first established between the science reasoning task, (SRT), results for control group students and their GCSE performances, and then applying the same relationship to students' SRT scores in experimental group to predict their examination grades. The difference between predicted and actual exam grade represents the residualized gain score, (rg score). The mean rg score for the control group was zero, by definition, which then provided a basis for the analysis of the effects of CASE intervention. The standard deviations of the rg scores and the probabilities that the mean scores in the experimental group were significantly different from the control means were also calculated.

In the discussion of their results, Adey and Shayer, (1993, pp.16-20), reported significant gains on the SRT post-test only in the experimental group of twelve year-old boys and no gains when the post-test was delayed by one year. They also reported gains for the twelve year-old boy and eleven year-old girl experimental groups in GCSE science, mathematics and English. Incidentally the twelve year-old girl experimental group also had gains in English, which Shayer argued could only be due to cognitive development, as "it just isn't plausible to believe that science process skills could transfer to English." (1999, p.891).

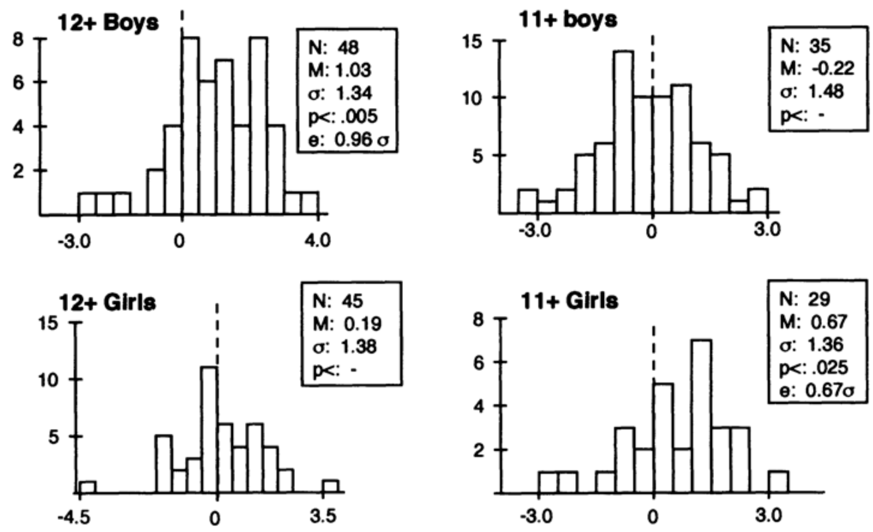


Figure 2.13 "Residualized gain in grades of experimental group on General Certificate of Secondary Education: science." (Adey & Shayer, 1993, p.19).

The publication of the results of CASE intervention in 1991 prompted great interest from a number of schools in England and Wales and as a consequence it was possible for the team to extend the programme to include over two thousand students, in eleven schools, in trials over subsequent years. In their analysis, the mean cognitive level of the school intake was plotted against the subsequent mean GCSE examination performance, (figure, 2.14), as a measure of added value. It can be seen from the data that all the CASE schools lie above the regression line for the control schools and, as the national average appears on the line, this indicates that the schools provide a representative sample.

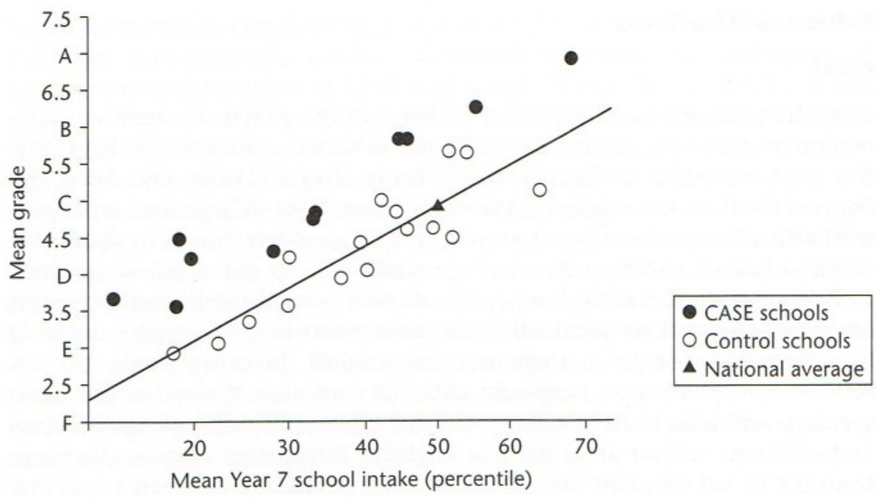


Figure 2.14 "GCSE 1999 science added-value" (Adey & Shayer, 2002, p. 10)

The positive impact was replicated by Jones, who compared standard assessment tasks, (SATs), results for students, with and without CASE intervention in five schools in Sunderland in the early 1990s, where improvements of half a SATs grade were reported, (Jones & Gott, 1998). Further positive results have been reported by Endler and Bond, (2000), in Australia, Mbano, (2003), in Malawi, Babai and Levit-Dori, (2009), in Israel and McCormack, (2009), in Ireland.

CASE has been identified by Black *et al*. (2006), as one of three highly effective interventions designed to promote the development of effective learning strategies in students, which fit under the umbrella of learning how to learn, (LH2L). They argue that the results from the large-scale trials over many years unequivocally demonstrate the ability of the intervention to raise standards.

The *Thinking Science* impact on cognitive development and performance has not been without critics however, with Jones and Gott, (1998), for example, questioning whether the results could be due to the Hawthorne effect; where the increased attention students receive by being part of a research program encourages them to work harder and perform better. They also point out that the focus is on students who benefit from the intervention and suggest that more research should be done with those who might be disadvantaged by the process. Mbano's results seem to negate Shayer and Adey's concept of a critical age, as improvements were seen regardless of the age at intervention. A critical age also sits a little bit askew with Shayer's ideas of eight to twelve year age gaps in a typical class of twelve year-old students.

2.3.6 Neurological maturity, gender and cognition

"Brain development in humans occurs stagewise in correlation with the onsets of the main Piagetian stages" according to Epstein, (2001, p.1), who goes on to comment that although increases in levels of cognition are dependent on physiological changes that have to first take place in the brain, there is some evidence that instructional or experiential inputs can be influential on final brain structure.

Prior to the technological advancements that led to non-invasive imaging techniques, such as magnetic resonance imaging, (MRI), positron emission tomography, (PET), diffusion tensor imaging, (DTI), and accelerator mass spectrometry, (AMS), inferences regarding brain growth on living subjects had to be made from observations such as the often cited measurements of increased head circumference with age. For a period of eighteen years, Eichorn and Bayley, (1962), meticulously recorded such circumferences from a small sample group of seventy-four white American individuals, born between 1928 and 1931, and concluded that maximal adolescent head growth in girls occurred between eleven and twelve years of age while in boys this was later, between fourteen and fifteen years; although in the discussion of their results they discarded the data that showed a male growth spurt between the ages of nine and ten, (equivalent to the one they quoted as maximal at age fourteen), by putting it down to a "change in anthrometrists at 10 years." (p.264).

The data on brain growth phases just discussed, was taken by Shayer and Adey, (1981, p.135), as support for their critical age concept; but in a later report they state incontrovertibly that when girls start an intervention program at age eleven, and boys at twelve, the corresponding effects are most marked and long lasting. They suggest that this "may be due to the different conjunction of the intervention program with critical periods for girls' and boys' cognitive development", (Adey & Shayer, 1993, p.27).

The change in circumference of one's head is rather distant from any understanding of brain development however, and somewhat akin to comparing the quality of goods in different shopping bags based on volume. And more so, as Tanner, (1978), argues, "brain size or brain weight is not a very satisfactory measurement" as "Different parts of the brain grow at different rates". Not surprisingly he concludes that "There are maturity gradients in the brain no less than in the bones of the skeleton." (p.140).

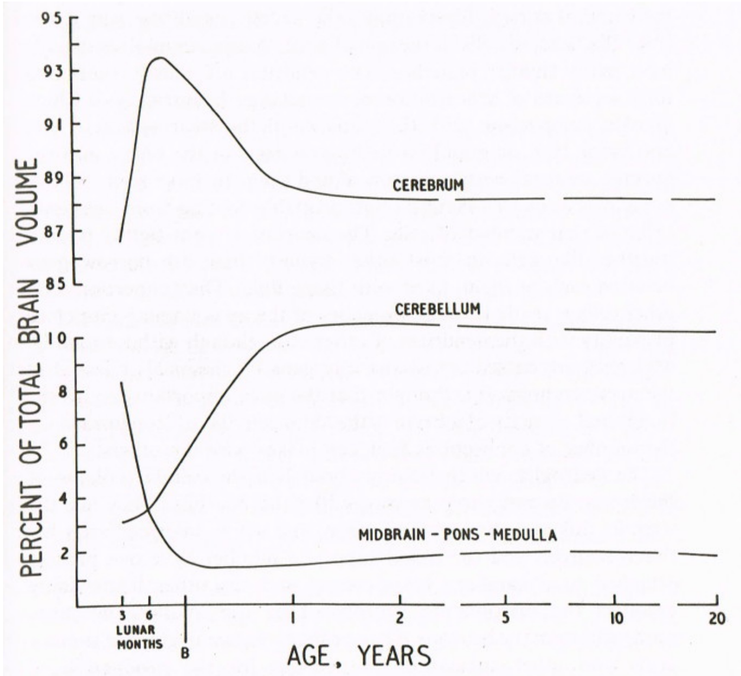


Figure 2.15 Percentage of their volume at birth reached at earlier months by parts of the brain and spinal cord, (Tanner, 1978, p.105).

Brain weight, head circumference, cerebral blood flow and cytological studies are cited by Epstein, (2001), as evidence to support biennial brain growth phases between the ages of two and four, six and eight, ten and twelve and fourteen and sixteen. During these growth periods he describes an increase in brain mass of, on average, between five and ten percent; as compared with the one percent in the intervening periods. This increase cannot be due to an increase in the number of neurons however, as studies by Bhardwaj *et al*. (2006), show that neurons are generated perinatally. The explanation for the increases in mass comes from cytological and imaging studies that demonstrate that this is due to greater arborisation of neurons and dendrites, the elongation of axons and myelination of the same, and pruning of redundant connections, (Amso, 2006). These changes in structure allow for new pathways to be made between different regions of the brain, which in turn, permit the move towards the higher levels of cognitive development. For example, during the growth spurt that begins around the age of six, new connections between distinct regions of the brain responsible for sensori-motor and cognitive functions are made and the new Piagetian cognitive level of concrete operations begins. According to Epstein, the growth spurts at ten and fourteen are novel in that they are characterised by very definite gender dimorphism, with the early phase showing greater brain growth in girls and the latter a corresponding growth in boys. Halpern *et al*. (2007), report that there are gender differences in brain structure, with females having a higher proportion of grey matter and males a corresponding higher proportion of white matter and cerebrospinal fluid. Results of research on the development of boys and girls, between the ages of five and sixteen, across seven cognitive domains show, however, that there are greater gender similarities than there are differences, (Ardila *et al*. 2011). Fischer, (2009), probably summarises Epstein most neatly by stating that cognitive and brain activity growth occur in tandem with growth spurts at particular ages.

Toepfer, a colleague of Epstein's, regarded a consideration of the 'brain rewiring' during periods of growth as of critical importance when considering the planning of school curricula and stated that:

> it is relatively easy for youngsters to initiate and develop new and higher level cognitive, thinking skills during the brain growth stages.
>
> (Toepfer, 1980, p.223)

He extends this statement to propose that during the intervals, or plateaus, between growth spurts it is almost impossible for new thinking skills to be developed. This is not entirely consistent with Epstein's position that the quality of the more complex networks being developed, (that make possible enhanced brain function), depend on:

> both the quality of existing networks that are connected by the added arborization and, also, the quality and quantity of the external inputs that generate consequential network changes.
>
> (Epstein, 2001, p.2)

If Toepfer's assertions are demonstrable, they would have significant implications for the use of cognitive acceleration programs such as *Thinking Science* with students in the twelve to fourteen slow growth interval and would likely produce results that would be contrary to those quoted by Adey and Shayer, (1993). Toepfer states, (p.225), "higher level skills cannot be initiated during such times", however he does suggest that pre-developed thinking skills may be fine-tuned. Haglund also sums up research on this period by stating, "curricula based on formal reasoning are not appropriate to youngsters twelve to fourteen years old." (1981, p.228).

Vygotsky, (1998), identifies the age of thirteen as a period of intellectual "crisis" characterized by a:

> decrease in success, decline in capacity for work, lack of harmony in the internal structure of personality, contraction and dying off of systems of previously established interests, and the negative, protesting character of behavior.
>
> (Vygotsky, 1998, p.193)

He accounts for this in terms of a cognitive shift, where the child changes the focus of attention from what is obvious, to understanding and deduction. Vygotsky's crisis at age thirteen corresponds to an often observed, and commented on, 'turn-off' in many second level students' attitudes to academic work, where it may be the case that their ZPD has been miscalculated by regarding their cognitive development as chronological rather than periodical.

Thus, we could present the division of age into periods in the following ways:

Crisis of the newborn.
Infancy (two months to one year).
Crisis at age one.
Early childhood (one to three years).
Crisis at age three.
Preschool age (three to seven years).
Crisis at age seven.
School age (eight to twelve years).
Crisis at age thirteen.
Age of puberty (fourteen to eighteen years).
Crisis at age seventeen.

Figure 2.16 Crises and development redrawn from the original, (Vygotsky, 1998, p.196)

The previous discussion identified that there are differences of opinion as to whether cognitive shifts occur concomitantly with biological development or as a consequence of it. In either event, it can be argued that the evidence shows that the relevant neural pathways need to be in place, or at least developing, before the skills of formal reasoning can be acquired. That is to say, it seems unlikely that formal reasoning would be observed prior to the brain growth spurt at age ten.

2.3.7 A summary of cognitive development

This section on cognitive development began by outlining the stage descriptors of Piaget's theory of genetic epistemology, through infant to adult thought processes. Out of this was drawn the principle that productive engagement with certain curricula concepts depends on neurobiology and thought processes having at least partially developed to a stage appropriate for their introduction. The importance of careful and considered curriculum mapping was also identified.

The work of Dasen, (section 2.3.3), waves a large red flag at the use of level descriptors as *carte blanche* indicators of an individual's cognitive ability as it shows that progress in different domains is not necessarily concomitant. In the next section of the literature review, on assessment, the use of the Structure of the Observed Learning Outcome, (SOLO), taxonomy will be identified as a tool to counter this issue.

Shayer & Adey's science reasoning tasks, (SRTs), the data that has been generated from them, and the work of other researchers, was included to highlight a recorded eight-year age gap in cognitive ability in a *standard* class of twelve-year-old students, and its possible knock-on effect with regard to engagement with curriculum content. Caution is reminded in ascribing definitive cognitive ability that may only be indicative of a student's lack of prior experience within a particular domain.

The Cognitive Acceleration through Science Education, (CASE), programme was described, as the structure of student action cycles, (SACs), that are the focus of this thesis, is designed to provide the CASE pillars of concrete preparation and cognitive conflict as well as opportunities for social construction, metacognition and bridging.

Schema theory, the reworking of Piaget and Inhelder, (1958), schemas will be integrated with the curriculum content of the specification for junior cycle science, (SJCS), to provide opportunities to develop thinking patterns across domains, as will be discussed further in the conceptual framework, (section 2.6).

2.4.1 An Introduction to Assessment

In the sections of the literature review that follow, a critique of various assessment strategies will be offered. Formative assessment, through the use of well-timed and appropriate feedback that students can make use of, will be discussed as well as the proposal that what is often passed off as formative feedback could be better described as deformative, conformative or transformative intervention. Questions are raised about the validity of quoted effect sizes by different researchers before real learning and learning how to learn, (LH2L), are mentioned. Finally, two assessment strategies that will be integral to the process of student action cycles, (SACs), are highlighted; namely the Structure of Observed Learning Outcome, (SOLO), taxonomy and strategies for assessment of inquiry learning in science, (SAILS).

2.4.2 Assessment *for* Learning

Assessment performs a number of functions, ranging from the summative, criterion based, factual recall examinations that are typically used for selection purposes and reporting on achievement towards specified goals, to formative, assistive, even a collaborative dialogic process, that supports the development of understanding and skills concomitantly with the learner. The former, as described in the section on diploma disease, (section 2.2.12), has the tendency to drive the process of acquisition of information towards accreditation rather than deep, meaningful understanding that could be described as wisdom. As a variety of terms are employed to describe different assessment processes, a few of these will now be detailed for clarity.

Summative assessment, the assessment *of* learning, (A*o*L), is typically criterion based and provides a measure of how successful a student has been in achieving particular goals. This is usually undertaken at the end of a teaching cycle and provides data that is often reported, or used for selection purposes.

Comparisons of a student's performance against previous attainment with an emphasis on the amount of effort that has been invested by the learner is described as ipsative assessment, and is most frequently used to reward this with the intention of enhancing motivation and task involvement.

The retrospective analysis of what a learner knows, and where difficulties might have arisen, falls under the heading of diagnostic assessment and is similar to formative assessment in that it is used to affect learning. However, the way it is used is analogous to knowing that a fuse has blown but not changing it until the appliance is next needed; as any intervention to move learning forward would take place at some point in the future.

Assessment *for* learning, (A*f*L), according to Black and Wiliam, (Wiliam, 2009, p.9), best describes “the purpose of the assessment”, while “the function it actually serves” should be regarded as formative assessment. This is a view not necessarily consistent with that of Pearson Education, (2005, p.9), who regard formative assessment as an instrument, and to this end had produced the PASeries, which “is the only formative assessment that is able to reliably forecast student achievement”. Shepard, (2008), and Popham, (2006), are both critical of this misuse of the term formative, as the PASeries would be better described as summative benchmarking, or interim diagnostic testing materials that can be used as an early warning system, but are not formative due to the delay in feedback.

Black and Wiliam’s definition of formative assessment, based on the prior work of Ramaprasad, (1983), is that it is a process that contributes to learning by providing informed feedback on work while it is being undertaken, identifying strengths, and areas for improvement, and affecting the route subsequently taken by the student, peer group or teacher. The teacher fulfils the role of a facilitator of learning rather than merely a repository of knowledge and skills that are there to be ‘cast as pearls before swine’.

> Feedback is information about the gap between the actual level and the reference level of a system parameter which is used to alter the gap in some way.
>
> (Ramaprasad, 1983, p.4)

It is remarked by Swaffield, (2011), that the etymological basis of the word 'assessment' is the Latin verb *assidere,* which translates as 'to sit beside', and that sitting beside a student and assisting their learning might be closer to the original intention of assessment than the current high-stakes formalized tests and examinations that the word is often equated with.

It has been suggested that the relationship between summative and formative assessments is much more complex, in that:

> Formative assessment then might be best conceived as neither a test nor a process, but some thoughtful integration of process *and* purposefully designed methodology or instrumentation.
>
> (Bennett, 2011, p.4)

In attempting to illustrate the importance of formative intervention, Wiliam, in his presentations, frequently uses the example of a pilot. His pilot knows how long a particular flight should take and in what direction to fly and then proceeds and lands at the closest airport that matches these criteria. When the pilot asks if they have arrived at the right location and is informed no, they tell the passengers to get out anyway as they have to get on with their next job. He equates this to teaching by suggesting that at the end of a taught unit of work students are tested, and for those that do well everything is satisfactory, but those who have failed to grasp concepts are left stranded as the teacher moves on to a new topic. A check on position by the pilot, or on progress by the teacher, would have allowed for course correction in the form of formative intervention.

A more succinct distinction between formative A*f*L and summative A*o*L is ascribed to Stake, (cited in Scriven, 1991 p.169), who suggests that “when the cook tastes the soup, that’s formative; when the guests taste the soup, that’s summative.”

Dynamic assessment, (Poehner, 2007, 2012), was a term developed by Luria, a member of the ‘Vygotsky Circle’, and popularized by Feuerstein, to draw a distinction between ‘static’ summative assessment and the practices of “organizing interactions to simultaneously assess learner development and move it forward”, (Poehner, 2012 p.620). Essentially the term describes formative assessment but as Leung, (2007), emphasizes, dynamic assessment is a process that is based in developmental theory and takes place firmly within Vygotsky’s zone of proximal development, (ZPD), rather than in *ad hoc* classroom practices. He further draws a division by proposing that dynamic assessment is aimed at long-term development rather than at helping students with specific short-term tasks. It should be noted that in his comparisons, Leung refers to A*f*L rather than formative assessment.

Formative assessment then, is the antithesis to the response in the old joke about a tourist looking for directions to Dublin and being told “If I were you I wouldn’t start from here”. To be effective, knowing exactly where a student is with their thoughts and skill set is the essential starting point to providing directions that assist the learner in proceeding towards their goals.

Effective formative assessment should be a positive, affirmative process that promotes learning and takes the individual's progress and effort into account. Feedback has to be given in such a way as to provide the ability to effect change. Wiliam, (2009, p.9), gives an example of a room thermostat that controls a central heating boiler; if the connection back to the boiler is broken then the thermostat can still respond to temperature summatively but not effect change formatively.

Shute makes the important point that feedback needs to be short, to the point and easy to understand if students are to pay any attention to it.

> Formative feedback might be likened to "a good murder" in that effective and useful feedback depends on three things: (a) *motive* (the student needs it), (b) *opportunity* (the student receives it in time to use it), and (c) *means* (the student is able and willing to use it).
>
> (Shute, 2008, p.175, italics in the original)

Further to the work of Shute, a fascinating piece of research by Hargreaves, (2013), probed the perceptions of students to feedback given. Many different effectors were identified, by first recording classroom events and then replaying them to the students involved, pausing at each feedback intervention, and asking what the teacher meant and how the students felt. The differing and often conflicting responses of students described reinforce Marshall and Drummond's, (2006), assertion that formulaic feedback does not necessarily move learning forward, and that this progression only occurs when the intervention is matched to the immediate and tangible needs of the learner.

	Where the learner is going	Where the learner is right now	How to get there
Teacher	1 Clarifying learning intentions and sharing the criteria for success	2 Engineering effective classroom discussions, activities and tasks that elicit evidence of learning	3 Providing feedback that moves learners forward
Peer	Understanding and sharing learning intentions and criteria for success	4 Activating students as instructional resources for one another	
Learner	Understanding learning intentions and criteria for success	5 Activating students as owners of their own learning	

Figure 2.17 Aspects of formative assessment redrawn from Wiliam, 2009, p.12

Wiliam identifies five key aspects of formative assessment, (Figure 2.17), with the first of these being the effective sharing of curriculum content and the criteria for success with the students. His second, third and fourth aspects have their basis in Vygotsky's theory of social constructivism, with knowledge and skills being co-constructed. As Vygotsky wrote:

> human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them.
>
> (Vygotsky,1978, p.88)

The third stage is merely another way of describing the provision of help from a more able peer within the construction zone, as is the fourth, which resonates with Vygotsky's collaborative and cooperative learning strategies. Reflection on learning, or metacognition, is his final aspect and this also includes the idea of personal ownership and motivation.

It is worth reviewing the five pillars of the Cognitive Acceleration through Science Education, (CASE), programme in line with Wiliam's aspects of formative assessment; namely concrete preparation, cognitive conflict, social construction, metacognition and bridging. One could argue that the first aspect has elements of concrete preparation, although Wiliam does not specify the need to establish the level of prior understanding, even though we must accept that "Any learning a child encounters in school always has a previous history", (Vygotsky, 1978, p.84). Social construction and metacognition are obvious within the scheme, and cognitive conflict may appear through the delivery of the curriculum content. What is possibly missing, or may need to be articulated more clearly, is bridging the learning into other contexts; although it could be argued that this would move the learner forward and could therefore be subsumed into aspect three.

2.4.3 Assessment *as* learning

More recent research on "Assessment *as* learning" (A*a*L), is mentioned by Dann, (2014), where she reflects on how students self-regulate their learning, what sense they make of feedback and how they use this, how they perceive the learning gap within their zone of proximal development, (ZPD), and the role of vocabulary in the assessment process. She suggests that "pupil involvement in assessment can feature as part of learning – that is assessment *as* learning", (p.150), but to do this students must develop a range of skills that allow them to set goals and evaluate their progress towards them.

Hattie and Jaeger comment that, when internalizing feedback, students may use "Self-status quo tendencies", (1998, p.116), which involve maintaining their concept of self-worth at all costs, and "Self-testing tendencies", where they look for confirmation or disconfirmation, or vary the process depending on circumstances. They warn that "students can bias feedback and select information that provides affirmation of their prior beliefs", (p.117), and that being effective as a facilitator "involves being aware of individual students' dispositions to receiving feedback information."

As is pointed out by Sadler, the implementation of effective formative assessment takes time, as students may not encounter such feedback in other curricular areas, but probably instead encounter a "wide variety of practices and teacher dispositions (many of which may appear incoherent or inconsistent)", (1998, p.78), and, as a consequence, students "may have to develop survival tactics as a coping response."

He continues by stating that the feedback process must be carried out for long enough that the process seems “normal and natural”, (1998, p.78), to the learner. Most importantly he highlights that it must not be assumed that students know how to act on feedback when it is given. Not only must feedback be appropriate to the individual learner, it must also be given greater status in the learning process than merely a terminal report on a particular assignment or performance. It also must not be assumed that all feedback is necessarily beneficial. Sadler also comments on the negative effects of negative feedback and states that this can be taken by the student as a personal criticism if it is based on cohort performance, which in turn can lead to situations where the teacher gives “praise for work of a quality that does not deserve it.”, (p.84). He argues the case for giving praise for effort leading to “higher self-esteem, more effort, and finally higher achievement.”

The results of the research conducted by Cowie, (2005), into student perceptions of A*f*L, with ten science classes of students between the ages of eleven and fifteen in New Zealand, demonstrate that social and academic goals interplay within the classroom, and unsurprisingly, affect the willingness of students to actively engage with the curriculum. The subjects of her research claimed that their thinking could not have been assessed unless the teacher had come round and spoken to them during class, and all stated that they would like more opportunities for informal, one-to-one, semi-private interactions of this type. Students highlighted the need for plain English rather than verbiage in responses and regarded a ‘put down’ verbal or written comment such as ‘That’s not right’, as showing a lack of respect that undermined the student-teacher relationship, and this led to a reduced inclination to interact. “…they appreciated teachers 'who respected the way you want to learn' and who 'let you learn yourself'", (p.148), and part of this involved feedback in the form of suggestions, because these allowed them to maintain an active role in making sense of their learning. The students recognized the time limitations for teacher interaction and recommended greater use of peer-assessment, as this could provide feedback when it was needed, and in a language that could be understood.

Black *et al*. (2003), question whether the 'letter' or the 'spirit' of formative assessment is applied in the classroom, to which Torrance, (2012), adds that it could possibly be better described as deformative, conformative or transformative assessment, depending on the approach used. He notes that students who receive critical comments, even when given advice on how to improve, are unlikely to make productive use of the feedback, especially if they disagree with the remarks made. If this critical feedback forms part of a catalogue of such events then students are more likely to perceive themselves as failures, and he describes this as deformative assessment. Torrance also makes reference to Sadler's interpretation of using formative assessment to 'close the gap' and argues that not only does this suggest "an incremental, building block view of knowledge.", (p.333), but also that closing the gap is not necessarily a good thing. He refers to Vygotsky's ZPD and states:

> the issue is not so much to close this 'gap' in any straightforward sense, but to explore and exploit the gaps between teacher and student, and between students' present and developing understanding through pedagogic action, so that learners come to understand what are the issues at stake, and what learning means for them.
>
> (Torrance, 2012, p.333)

When 'closing the gap' is limited to providing feedback that helps a student to 'jump through hoops' towards completing a learning goal, only to meet the objectives of a course, Torrance describes this as conformative feedback. It is where the process might be more appropriately labelled assessment for criteria compliance than A*f*L. Transformative feedback, on the other hand, develops critical thinking and helps produce flexible and self-regulating learners.

2.4.4 Results under scrutiny

Bennett raises concerns about the validity of the reported effects of formative assessment and regards them as "suspect, to say the least", (2011, p.20). Black and Wiliam make the assertion in "Inside the Black Box", based on their previous review of published research, (1998a), that the "Typical effect sizes of the formative assessment experiments were between 0.4 and 0.7.", (1998b, p.141), which correlates, for the lower value, to moving an average student up by fifteen percentage points, and with the higher one, to moving "a nation in the middle of the pack of 41 countries (e.g., the U.S.) to one of the top five." The effect size is calculated by dividing the average test scores of students with intervention by the average scores of those in control groups.

These results are however, "a mischaracterization that has essentially become the educational equivalent of urban legend", according to Bennett, (2011, p.12), as they are not truly representative of the pair's original findings. Black and Wiliam's value of 0.4 appears to have been taken from the meta-analysis of one hundred and thirty-one papers mentioning ‘feedback intervention’ conducted by Kluger and DeNisi, (1996, p.258), who regarded this as “a moderate positive effect on performance”, but also noted that “over 38% of the effects were negative.” The more dramatic effect size of 0.7 looks like it comes from the meta-analysis that they cite, conducted by Fuchs and Fuchs, (1986), on twenty journal articles, twenty-five dissertations and fifty-one unpublished papers covering formative intervention on children ranging from pre-school age up to eight years old, the majority of whom were identified as having “mild handicaps”, (Black & Wiliam, 1998a, p.15), and who came under the umbrella of special needs intervention. As the Fuchs’ report in their paper, this:

> suggests that one can expect handicapped students whose individualized education programs are monitored systematically and developed formatively over time to achieve, on average, .7 standard deviation units higher than students whose programs are not systematically monitored and developed formatively.
>
> (Fuchs & Fuchs, 1986, p.205)

The number of effect sizes quoted is ninety-six, (n=96), with one third of these also receiving “behaviour modification”. Black and Wiliam never specify exactly where they took their 0.4 and 0.7 values from, or why they ignored the reports of negative impact. There were seven other pieces of research that the two used as examples in their initial review and it might have seemed prudent for them to conduct a meta-analysis of the results of these but, as they note themselves, “the underlying differences between the studies are such that any amalgamations of their results would have little meaning.” as “they differ in the nature of the data which may have been collected - -

or ignored.", (1998a, p.53). The question might be asked as to whether the original studies they took their values from also had significant underlying differences.

In a later piece of analysis by Black *et al*. (2003), the difficulty in obtaining unbiased, stringent data is highlighted by the following quote, from the King's Medway Oxford Formative Assessment Project, (KMOFAP), who examined the reported learning gains for a teacher who submitted two control groups, where:

> the comparison with the same teacher in a previous year gave a large positive effect (1.15), while comparison with another more experienced teacher with a parallel class in the same year gave the negative effect (-0.31).
>
> (Black *et al*., 2003, p.27)

Hattie and Jaeger exceed Black and Wiliam's claims for the value of formative assessment, and are unequivocal when they state that "the most powerful single moderator that enhances achievement is feedback", (p.114), quoting an average effect size of 0.91 from 87 meta-analyses. They go on to note that the effectiveness of feedback is ameliorated by the format in which it is delivered such that:

> There are forms of feedback that are positive, such as reinforcement (1.13), corrective feed-back (0.84), remediation and feedback (0.65), diagnoses and feedback (0.52), and mastery learning (0.50). There are also less effective forms such as extrinsic rewards (0.37), immediate versus delayed (0.28) and punishment (0.20).
>
> (Hattie & Jaeger, 1998, p.114)

It may well be possible that, as Bennett states with regard to formative assessment, "the magnitude of commonly made quantitative claims for effectiveness is suspect, derived from untraceable, flawed, dated, or unpublished sources.", (Bennett, 2011, p.5), particularly when, as Torrance notes:

> it is now widely observed that formative assessment is often developed and used… to improve test scores and examination grades, rather than to improve the experience of learning and the quality and diversity of learning outcomes.
>
> (Torrance, 2012, p.328)

2.4.5 Real learning

An important assumption about the purpose of education, in that it should be to effect *real* learning, that involves deep understanding, rather than a superficial recall of a mélange of disparate information is proposed by Harlen and James. They do recognize that rote learning has a place for such functions as memorizing spellings and multiplication tables, but suggest that there should be greater emphasis on developing transversal skills that can be applied to resolve problems not closely related to ones students are familiar with. This recognizes the importance of bridging. Furthermore, they propose that assessment for real learning has a very different role than the summative function of an end of module memory test, which although important in the overall educational process, is less valuable on a day-to-day basis. In conclusion, they warn that the practice of rote learning instruction to program students with information to pass examinations "will inevitably shift teaching and learning away from understanding", (1997, p.370), much as Huxley said in 1904, "They work to pass, not to know;", (para.75).

Marton and Säljö distinguish between surface learning and deep learning, where in the former there is an absence of "active and reflective attitude", (1997, p.49), towards the material, and where motivation is extrinsic; that is to say, the learning is driven by the need to fulfil the demands raised by others. Harlen and James point out that efficient learning is a combination of deep and surface learning, as it would be impossible to learn everything in depth. They propose that this real, deep learning is a progression from what has already been constructed by the learner towards big ideas and skills for living and learning that will impact on the learner's attitudes and values, and that it has to have more importance and usefulness than just regurgitating information to pass tests.

2.4.6 Towards Learning Autonomy

The impact of "Inside the Black Box", (Black & Wiliam, 1998b), was such that in the late 1990s the assessment task group of the British Educational Research Association invited Black and Wiliam to conduct a literature review on formative assessment practices. This was supported by the Nuffield Foundation who subsequently went on to provide funding for the King's Medway Oxford Formative Assessment Project, (KMOFAP), which conducted research in six schools and with forty-eight teachers of science, mathematics and English. One of the conclusions they reached was that

“What is much more important for the long term is that students have acquired the ability to ‘learn how to learn’”, (Black *et al*. 2003, p.67).

Subsequently, between the years 2001 to 2005, a major British research project, funded by the Economic and Social Research Council, (ESRC), and called the Teaching and Learning Research Programme, (TLRP), was undertaken. Involved with this were three of the original six KMOFAP researchers, four universities – Cambridge, King’s College London, the Open University and Reading University - and the students and teachers of forty project schools and ten trial schools. Out of this was born the Learning How to Learn, (LH2L), project which identified the need for lifelong learning as a priority to keep up with the rapidly increasing creation of knowledge and developing technologies that may leave students with out-dated skill sets by the time they leave formal education. As Black and his colleagues identify, it is no longer good enough to provide students with content to learn; they also have to be helped to develop the ability and inclination to continue learning throughout their life. (Black *et al*. 2006). From this came some clarification of the rhetoric surrounding the concept of LH2L, (as opposed to Learning to Learn, (L_2L)), and its position in the hierarchy of pedagogies leading from assessment *for* learning, (A*f*L), to learning autonomy, (LA), (James *et al*. 2007, p.26). Members of the project describe LH2L as a process that develops skills and understanding in the learner around the best way to go about learning new material, whether it be school work, or any other form of knowledge or ability. This pedagogy moves the focus from the more teacher-centred approach of A*f*L, on which it is based, to student-centred strategies that are underpinned by practice that is aimed at making learning explicit, encouraging independent learning and reflection on personal performance.

One of the major findings of the research team was that LH2L is often highly contextualized and so is difficult to divorce from the act of learning something; which has implications for 'bolt-on' study skills packages that are, in many cases, the norm. Black and his research team, (Black *et al*. 2006), identified three particular learning practices that promote LH2L and these were the Adey, Shayer and Yates', (2001), *Thinking Science* CASE program (section 2.3.4), Mercer's 'Talk Lessons' (1999, 2002) (section 2.5.3) and, of course, A*f*L as already discussed. These three learning practices will be integral to the student action cycles, (SACs), as will be discussed in the conceptual framework, (section 2.6).

2.4.7 Strategies that promote effective and deep learning

Within assessment *for* learning, (A*f*L), the King's Medway Oxford Formative Assessment Project, (KMOFAP), team, (Black *et al*. 2006), focused on developing strategies to promote effective questioning, feedback through marking, peer and self-assessment by students, and the formative use of summative tests.

Their findings were that effective questioning is unlikely to be achieved if the time before a teacher responds, teacher wait time, is too rapid. They reasoned that short teacher wait time provides insufficient student thinking time, which in turn results in simple, closed responses to simple, closed questions aimed at the recall of facts rather than the development of thinking skills and dialogue beyond a superficial level. This was informed by the previous work of Rowe, (1974), who conducted a five year study, in the late nineteen sixties and early seventies, into the impact of teacher wait time on language and logic development in school science classes. She noted that teachers allowed, on average, one second for students to start responding to a posed question before either repeating the question, rephrasing it, or calling on others to respond. Where a response was elicited she found that teachers waited an average of 0.9 seconds before commenting on the response, asking another question, or moving on to a new topic. In addition, she noted that students frequently exposed to short wait time instruction were more likely to ignore information supplied by their peers, and used this information, which she admitted is “Circumstantial evidence” to conclude that “conversation in which students build on each other’s ideas cannot develop in classrooms operated on a fast wait time schedule.” (Rowe, 1974, p.86).

When wait time was increased, nine separate consequences were observed. The length and complexity of student responses increased, as well as the number of unsolicited but appropriate responses. Students less frequently answered ‘I don’t know’, or gave no response, and were also observed to give speculative responses more often. Confidence, as measured by a reduction in inflected statements, grew; although Rowe notes that where rewards for correct answers were frequently given, the use of inflection, as in ‘have I given the answer you wanted from me?’ tended to remain. Students were also observed to listen to each other more.

As well as an increase in inferential statements from students, the number of questions asked by them, and experiments suggested, also showed an increase. Finally, "Slow" students' contributions increased. None of this should come as a surprise as extending wait time allows for greater think time and, particularly importantly for children who are still developing their linguistic skills, the opportunity, and space, to formulate an appropriate response.

In discussing the varied impacts of feedback through marking on student performance, Black *et al*. refer to a paper written in 1988 by Butler, who undertook research that replicated much previous work in this field, (Nicholls 1979, 1984b; Deci & Ryan 1980, 1985). Butler investigated the effects of grade only, grade and comment, and comment only feedback on a sample of 132 eleven year-old "predominantly middle-class", mixed ability, Jewish Israeli students in an attempt to determine whether the style of teacher response had any impact on students' intrinsic motivation and performance.

She argues that "by fourth grade most pupils have achieved a differentiated concept of ability as a stable trait best assessed by comparison with others", (p.3), which consequently initiates a shift in the perception of importance away from task-involving formative feedback to ego-involving performance grades, which have higher currency, in the process of attempting to prove self-worth publicly. When grades, with or without added comments, were reported, a shift to ego-involving motivation was observed. Immediate interest and convergent thinking were maintained for high achievers but diminished for the less able; as did subsequent interest for all students. Butler also noticed that a:

> narrow preoccupation with grade attainment seems to affect the quality, if not quantity, of immediate task performance, and to undermine divergent thinking in particular.
>
> (Butler, 1988, p.12)

Where comments and grades were recorded, the students questioned only recalled the grade allocated, and a bad performance was not ameliorated by a positive teacher comment. Further evidence showed that when comment only feedback was given, task involvement and interest as well as divergent, creative thinking and convergent thinking, focusing on correct answers were maintained throughout the group. This is possibly not surprising as ego-involved motivation requires social comparison for its maintenance and is therefore impeded when grades are not allocated.

Discussion amongst teachers involved in the KMOFAP reinforced the findings of Butler; namely that students rarely read comments if given marks as well, and that they would consistently compare grades with peers.

They also noted that students were rarely given class time to read and act on written feedback and suggested that it was highly unlikely that they would undertake this at home. Furthermore, the recurrence of similar comments in student's copies over time indicated that little attention to, or action on them was taken. Where students did engage with feedback, the brevity of the comments often given, which could even be limited to a single word, restricted the possibility of improvement. This was further reinforcement for the findings of Kluger and DeNisi's, (1996), meta-analysis, conducted around five years previously, which had shown that feedback only leads to learning gains when guidance on how to improve is provided.

When students were asked for their input they requested that teachers not use red ink, which they felt spoiled their work, and to write legibly and with meaning and appropriate language such that the intention could be understood. These discoveries led the teachers of KMOFAP to initiated the process of providing feedback that focused on what had been achieved, what had to be worked on, and also on encouraging the learner to act on the feedback with support for them to do it. The end result was the introduction of comment and target only marking with an indication of the minimum amount of follow up work required by the student; effectively taking on the form of dialogue in writing. Time was also allocated in class, planned as part of the overall learning process, to redraft work and reflect on progress. In a reiteration of Butler's position, Black *et al*. validate this approach with the statement that, "In general, feedback given as rewards or grades enhances ego rather than task involvement", (2003, p.46), and "focuses student's attention on their 'ability' rather than on the importance of effort, damaging the self-esteem of low attainers."

Moving the focus from teacher to learner by employing self- and peer-assessment strategies is regarded as fundamental to A*f*L by Black *et al*. who clearly extol the position that students should be encouraged to take responsibility for their own learning. To do this, they argue, students must be given a clear indication of learning goals and what they have to do to achieve them. In addition, in order to make the whole process manageable, they recommend that students should be encouraged to structure an overview of the curriculum by thinking of their learning as a set of sequential, manageable goals. The group also suggest that practice in developing objectivity through peer-assessment may be a prior requirement for valid self-assessment and note two observable benefits from developing opportunities for the former; the first being that the prospect of having one's work assessed by one's peers has been shown to motivate greater attention to detail and, the second, that the language used for feedback is generally in 'student speak' and as such, is more meaningful. To facilitate any assessment however, criteria for success must to be clarified and the use of concrete examples to model these is proposed.

The position that peer-assessment can help develop the objectivity needed for self-assessment has been challenged by contrary results from research into students' views of this process, conducted by Hanrahan and Isaacs, (2001). In summary, selected quotes indicated that the students had difficulty with peer-assessment, as they felt uncomfortable in having peers read their work, and were equally discommoded by being required to critique others' material. Hanrahan and Isaacs also reported that students found it very difficult to be objective as, "obviously you are going to be relatively easy on yourself" because "automatically you believe that you meet the criteria" even though you "may in fact fall short in others eyes." (p.59). There were positives though, with students reporting a better understanding of marking schemes, valuing greater feedback, having the opportunity to see good and bad work, and being motivated to impress their peers.

Research completed in Canada into teachers' use, and expectations of, self- and peer-assessment by Noonan and Duncan found that, to a large extent, outcomes were self-fulfilling; that is to say, teachers who seldom, or never, employed such assessment strategies used the excuses that "high school students lack the maturity to be truthful and/or objective", (2005, p.5), or "*can be too negative with themselves and others*", (italics in the original). Teachers who reported "somewhat" using the pedagogy either did so summatively, to focus on achievement, attitude, effort and participation, or formatively and metacognitively to elicit student's perceptions of their own progress, to encourage them to be accountable for their learning to themselves and to their peers, or to create positive environments for learning.

The results of research on students' performance and attitudes by Kitsantas *et al*. indicate that where the focus is outcome goal orientation, self-evaluation is a valuable learning instrument but can have a negative impact when focusing "on process goals as they are learning a procedural skill", (2004, p.285).

With regard to the interplay between self-assessment and task- or ego-involving engagement there is a danger that the process can become normative, as in the research conducted by Blatchford, (2006). In his study students, between the ages of seven and sixteen, were expected to make assessments of their progress relative to that of their peers, rather than on their own personal conceptions of performance.

The effects of self-assessment on terminal examination performance in ten high schools in Barbados over a three-year period, between 1998 and 2000, was conducted by McDonald and Boud, (2003). Their sample size, those students receiving self-assessment training, constituted 25.2% of the total student year cohort for the country. Results from the students that received self-assessment training showed consistent positive effect sizes varying between 0.13 and 0.26 across the areas of business studies, humanities, science and technical studies. In addition students reported that they regarded the training as beneficial to them rather than an additional burden in their final year. But, more significantly from an assessment *for* learning, (A*f*L) perspective, "Eighty-seven percent of the respondents to the survey claimed that they were able to see how all subject disciplines were integrated into the whole process of learning." (p.215). As a *caveat*, McDonald and Boud do concede that there may have been a "significant Hawthorne Effect" due to the positive learning environments created by the innovation, but conclude that providing training in self-assessment can improve learning outcomes, as displayed in examination performance.

Traffic-lighting performance in summative tests for formative revision, and reflection on topics that students are finding problematic, is proposed by Black *et al*. (2006). They also suggest that expecting students to plan units of work, and then explain these to their peers, would be an excellent process, and highly formative in structure. Other possibilities include having students generate exam questions and model answers; although this approach would surely encourage surface learning rather than deep meaningful learning that is the preferred outcome. Similar to this approach is the suggestion of peer test marking after the group collective has first formulated a marking scheme. A final formative use of summative assessment, they suggest, is for students to identify which questions have been poorly answered by them and focus on these for improvement in future tests. This exam focus by the group is in contrast to their original position on assessment *for* learning where they stated that “Such tests should be used to chart learning occasionally rather than to dominate the assessment picture for both teachers and students”, (Black *et al*. 2003, p.56)

2.4.8 “Evaluating the Quality of Learning”

The hierarchical Structure of the Observed Learning Outcome, (SOLO), taxonomy, (Biggs, 1979; Biggs & Collis, 1982), is a criterion referenced measure of the quality of learning instrument that can be used to assess the structural organisation of learned material, to discriminate between well-assimilated and poorly integrated information. In essence it can be used to measure the development of quality in thought processes through the analysis of responses to problems; and also to distinguish between deep and surface learning. It differs from Blooms taxonomy in that SOLO is used to evaluate open-ended responses rather than to set questions and is therefore retrospective in its function, rather than an instructional tool. It also differs from standard summative assessments, that quantitatively measure *how much* is remembered, in that it qualitatively measures *how well* information has been processed in such a way that it can be used formatively to provide feedback to the student, to assist with their cognitive development.

The levels identified by SOLO show a high level of congruence with the Piagetian stages of cognitive development but overcome the problem of labelling a student with a level that might not be demonstrable in all domains. Piaget referred to this as *décalage*; where students under certain conditions perform tasks typical of a particular stage with ease, but in slightly different circumstances, are unable to do so. Using SOLO resolves the alignment issues of *décalage* by transferring the label from the student to the response; as, although the student's cognitive level might set an upper limit of functioning in a Piagetian sense, a variety of other components, such as the level of motivation, prior knowledge of the task, or a particular aptitude within a domain, might affect whether or not the student functions at that particular level. Once this is taken into consideration there is no longer an issue in accepting that on one particular task a student might offer a concrete operational response and in another situation provide an example of formal operational thinking. Indeed, SOLO, in evaluating the responses to a task, rather than the student, removes the 'chicken-and-egg' scenario of Vygotsky's learning-leads-development and Piaget's development-before-learning.

The application of SOLO in evaluating the quality of outcome in relation to a student action cycle (SAC) trigger scenario may be found in Appendix I where the five categories of response, namely prestructural, unistructural, multistructural, relational and extended abstract, are illustrated.

It has been argued however that there is conceptual ambiguity in the structure of SOLO that makes the categorization of responses difficult to replicate between markers and as a result of this Chan *et al*. (2002), recommend introducing sub-levels to reduce this problem. To do this they split both the multistructural and relational descriptors into low, medium and high giving nine SOLO levels in their modified version. The results of their research seem to indicate that this is an improvement, but they are keen to acknowledge that further work would be required to verify this.

2.4.9 SAILS

SAILS, Strategies for Assessment of Inquiry Learning in Science, (Finlayson, McLoughlin & McCabe, 2015), was a three-year project, (2012-2015), funded under the EU Framework Seven programme, that involved over 2,500 second level teachers as well as researchers, students and industry from 12 countries across Europe. The aim of this venture was to promote and facilitate the incorporation of inquiry based approaches to teaching, learning and assessment within second level classrooms. The final product of SAILS was a legacy website, (sails-project.eu/index.html), that contains 19 units that showcase methods for embedding inquiry processes and assessment opportunities within lessons; as well as case studies, (>80), and recordings that illustrate these processes within a number of classrooms; including that of the author of this thesis, and his delivery to the final SAILS conference in the European Parliament. Each unit exemplifies methods by which evidence of inquiry skills, content knowledge, scientific literacy and scientific reasoning may be collected and assessed through a variety of techniques, such as analysing classroom dialogue, student artefacts and presentations, teacher observations, peer and self assessment and the use of rubrics. In providing support materials and assessment models, SAILS moves beyond the rhetoric of assessment *for* learning (A*f*L), (Harrison, 2014), and provides tangible materials that can be adapted by practitioners to suit the demands of their classroom.

In particular the SAILS project focused on supporting the development of the six skills and competences of developing hypotheses, working collaboratively, forming coherent arguments, planning investigations, scientific reasoning and scientific literacy through the careful selection of activities that promoted these. Integral to each unit then, are the inquiry approach, the development of skills and competences and the provision of assessment opportunities.

2.4.10 To sum up

The previous sections examined the use of formative assessment, in particular as a method for providing informative feedback to move learning forward, and as such described the 'oil' that will be used to lubricate the structure of the student action cycles, (SACs), to keep them turning.

The practice of *sitting beside* students and helping them to identify where they are, where they are going, and how best to get there, will be discussed further in the conceptual framework.

Taking Dann's, (2014), commentary on assessment *as* learning, (A*a*L), and involving students in self and peer assessment, while taking into consideration different social and academic goals, lie behind three of the stages of the SACs; namely establishing success criteria, evaluating, and reflecting. The student centred focus of the SACs will allow for Cowie's, (2005), 'learning for yourself and in your own way'.

The differing effect sizes reported for formative intervention were discussed and, though their reliability was called into question, the social construction that is possible through the process is not disputed.

The interaction between deep and surface learning and the active and reflective attitude to study in learning how to learn (LH2L), as were discussed, are firmly embedded in the metacognitive loops of the SACs.

Wait time, comment only, task involving marking in a manner that doesn't cover a student's work with graffiti, the use of self and peer assessment, analysis using the Structure of the Observed Learning Outcome, (SOLO), and a variety of the tools from Strategies for Assessment of Inquiry Learning in Science, (SAILS), will all feed into the conceptual framework.

2.5.1 An introduction to strategies that promote deep learning

This last section of the literature review, before a discussion of the conceptual framework, addresses the use of concept cartoons to establish learning context, and

Talk Lessons to help develop effective classroom conversation. It describes how concept cartoons, in addition to providing opportunities to evaluate alternative conceptions, present science as a unified topic, where different branches intertwine, and a process that is more than finding a right answer. The development of exploratory group talk through practice and reflection provided by Talk Lessons is also examined.

2.5.2 The use of Concept cartoons in promoting learning

> The learner's alternative conceptions of phenomena in science and the learner's thought processes, including metacognition and strategies of comprehension, attention, attribution, and generation, become especially important in teaching science for all students. Conventional methods of covering subject matter and presenting only the scientists' view of scientific phenomena clearly do not effectively teach science to all students.
>
> (Wittrock, 1994, p.30)

Concept cartoons, (Keogh & Naylor, 1999; Naylor & Keogh, 2000,2010; Moules *et al*., 2015), are visual representations of scientific ideas in dialogue form, set in student accessible situations, that present, with equal status, different and alternative explanations for a variety of phenomena based on extensive research, (Driver *et al*., 1994), into children's ideas on the world around them. By creating opportunities for focused discussions amongst peers, as opposed to providing concept definitions that are expected be rote learned without deeper understanding, they lend themselves to a constructivist approach to leaning in science, (Balim *et al*., 2016: Kabapinar, 2005; Minárechová, 2016), such that prior experience is used to interpret the illustrations and then construct new knowledge by adapting or adding to previous conceptions.

Although the depictions in the original cartoons were of individuals presenting one conception, this soon developed into several characters presenting a selection of ideas, as the researchers, (Keogh & Naylor, 1999; Naylor & Keogh, 2000), reported that a single focus could reinforce, rather than dispel, alternative frameworks. In addition, they state that including dialogue helps to dissipate students' beliefs that there is only one right answer to a question, and present a view of science where all ideas are valued.

The current series are designed to probe understanding, and pre-conceptions, by proposing alternatives that may not have been considered previously, and the cognitive conflict that is then engendered is used to ensure that alternative conceptions that are misaligned with conventional thought may be addressed. Elicitation and restructuring through discussion of the drawings with peers is important in the construction of new knowledge. There is never a single right answer but rather a selection of logical, often naive, alternatives to help ensure that students at different cognitive levels are able to engage meaningfully with them; from pre-operational through concrete to formal operational thinking.

Metacognitive skills may be developed through asking students to legitimize different alternatives, think about the reasons for their own ideas, search for corroborative evidence, discuss their learning and that of others and so induce creativity in answers. Realising that others have ideas that may be valid was discussed previously as a characteristic of Piaget's concrete operational stage of cognitive development, (section 2.3.2).

The cartoons also typically draw on more than one branch of science, and so help to counter the belief that the subject is merely a collection of unconnected facts. For example, "Moon Rock", illustrated on the next page, (Figure 2.18), questions whether a rock will sink in a trough of water on the Moon. The concepts behind this cartoon are that the mass and volume of both the water and rock remain constant and therefore so do their respective densities, however as the force of gravity is less on the moon, the rate at which the rock will sink is reduced. Keogh and Naylor report that even physics graduates had the same level of understanding as an 11 year-old, and quoted the response as "… you know the theory behind it but never related it to everyday situations." (Keogh & Naylor, 1999, p.441).

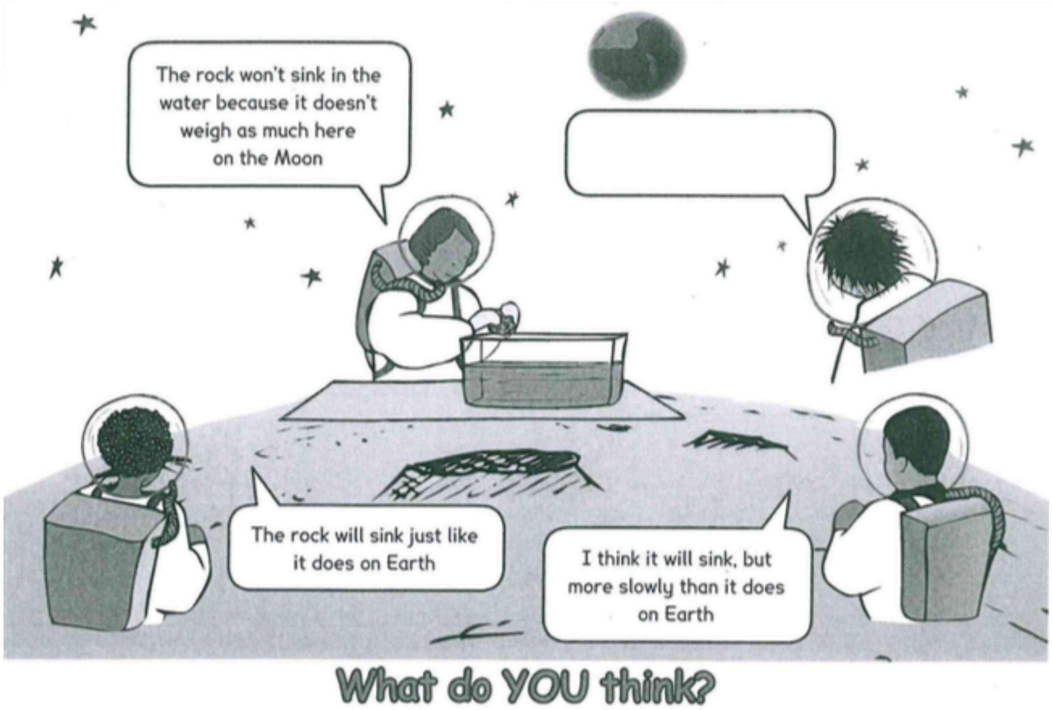


Figure 2.18 Moon Rock, from the original in Naylor & Keogh, 2010, Science Concept Cartoons: Set 1 – Revised Edition, p.96 with the kind permission of the publishers.

In his discussion of generative teaching, Wittrock, (1994), refers to the use of powerful stimuli to engage, such as the concept cartoons, which in themselves are highly motivating as they focus attention on constructing meaning through active engagement to resolve cognitive conflict.

To conclude,

> A straightforward learning of concepts always proves impossible and educationally fruitless. Usually, any teacher setting out on this road achieves nothing except a meaningless acquisition of words, mere verbalization in children, which is nothing more than simulation and imitation of corresponding concepts which, in reality, are concealing a vacuum.
>
> (Vygotsky, 1935/1994, p.356)

2.5.3 The cooperative controversy of Talk Lessons

Mercer, (2000, 2002), argues that a fundamental role of education should be to develop linguistic skills in students such that they are then able to use language as a tool for collective intellectual activity and that, secondary to this, providing opportunities for culturally-based classroom group discussion impacts significantly on students' intellectual development. This is largely a reiteration of Vygotsky's proposal that speech between students is a mediator in development such that by talking with others, students develop frames that they can later use for thinking on their own.

> Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, *between* people (*interpsychological*), and then *inside* the child (*intrapsychological*). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relations between human individuals.
>
> (Vygotsky, 1978, p57 italics in the original)

Language is used first as a cultural tool, through social interaction, and then as a psychological tool, for cognitive development.

Interpersonal social construction, often between the teacher and learner, where shared understanding is developed, is described by Mercer as the intermental development zone, (IDZ), and he refers to this as a fluid, dynamic frame of reference that changes constantly as dialogue between the participants evolves. The IDZ is essentially a scaffolded learning platform that provides an interactive learning-and-teaching environment that depends for its success on participation and commitment from all parties. He tells us that an IDZ does not evolve by chance but needs to be created, and maintained, and is only successful when connections between learning goals, the learners' existing knowledge, motivation and capabilities are matched.

Several characteristics shown by effective teachers in establishing an IDZ have been described by Mercer, (2002), such as: the use of question-and–answer sessions to both test knowledge acquisition and guide the development of understanding; using 'why?' questions to encourage students to reason and reflect on what they are doing; teaching problem solving strategies in addition to subject content to help allow students to make sense of what they were learning; ensuring the meaning and purpose of classroom activities are clearly explained to allow students the opportunities to make explicit their own thought processes, and; that effective teachers encourage students to take a more active, vocal role in class by providing opportunities for group discussion with support structures in place.

This separation, by Mercer, of styles of effective teaching from the learning-and-teaching dialectic of the IDZ is slightly at odds with his first assertion of their unity from a sociocultural perspective. Mercer reminds us that Vygotsky used the term *obuchenie* in reference to the interaction between teacher and learner and, that in Russian, this word refers to the activities of both the teacher and the learner together that lead to a concomitant transformation in <u>both</u> parties. Vygotsky regarded teaching-and-leaning as unitary, in the same way as thought-and-language, and used the analogy of water, (1986, p.4), to explain how problematic the analyses of individual components of such compound structures are; neither hydrogen nor oxygen exhibit the properties of H_2O. Thus separating the actions of effective teachers from *obuchenie* surely has the potential to distort the sociocultural perspective. After saying this, Cole argues that Western cultures focus more on learning as opposed to the Russian focus on teaching, and that Vygotsky's use of *obuchenie* refers to "*deliberately organized instruction in school*", (Cole, 2009, p.294 italics in the original).

The Thinking Together research, (https://thinkingtogether.educ.cam.ac.uk ; Wegerif *et al*. 2005), first conducted by Wegerif in 1996, showed that simply providing opportunities for collaboration can often be unproductive and that students need to learn how to use talk as a problem-solving and learning tool. The types of student interaction that typically occur are classified under the three headings of disputational, cumulative and exploratory talk.

In disputational talk exchanges are often short, defensive or competitive and defined by statements that assert an individuals position. There is frequently disagreement and tension, and rarely are resources effectively shared, positive suggestions made, or constructive criticism offered.

Cumulative talk is slightly more productive, in that common knowledge is constructed within the group, but this is not critically assessed and is marked by confirmations, elaborations and reiterations of the material under consideration. There is often little challenge and any cognitive conflict is conveniently ignored.

Critical but constructive and equitable discourse is characteristic of exploratory talk. Statements are discussed, challenged, verified or refuted with the proffering of alternative solutions. All discussants are active participants and all opinions are sought and valued with decisions made by the consensus of the group.

Talk Lessons, (Dawes, Mercer & Wegerif, 2000), evolved out of extensive research into classroom communications and describe a set of teacher-directed activities first provided to groups of students, aged between the ages of 8 and 11, in the United Kingdom in the 1990s. These lessons focus on how students talk amongst themselves, set ground rules and develop skills for effective collaborative discourse, while also examining how language might be used to help solve problems. The skills of talking, listening and collaborating are first practiced in small group activities, and then a class plenary provides opportunities for all to reflect on the learning that has taken place.

Analysing student performance on the Raven's Progressive Matrices, a non-verbal reasoning test, assessed the effectiveness of the Talk Lessons program. Pre- and post-treatment testing was performed on groups of students who had undertaken the program, (n=60), and compared against a matched class control group, (n=64). What was discovered was that the quality of collective reasoning and the incidences, duration and depth of group exploratory talk from those who had undertaken the programme was significantly improved, (Mercer, Wegerif & Dawes, 1999; Phillipson & Wegerif, 2017). Interestingly, and in support of Vygotsky's assertion that the interpsychological practice of talking with others helps to develop intrapsychological frames for individual development, the same study also showed that students who had followed the program did significantly better than the control group when set a second Raven's test to be completed on their own. That is to say their individual cognition had been improved by collaborative problem solving.

> *human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them.*
>
> (Vygotsky 1978, p.88 italics in the original)

2.5.4 Summed up

As will be described in the conceptual framework that follows, Talk Lessons provide opportunities for developing effective communication skills that are essential for collaboration during the process of student action cycles, (SACs), as identified by the key skill of 'working with others'. Concept cartoons, based on the work of Driver *et al*. (1994), allow the learners' perspectives to be taken into account and also provide a stimulus to engage.

2.6 A conceptual framework

Up until the introduction of the new specification, success in junior certificate science was predominantly measured by performance in periodic, and terminal examinations. Reporting to parents was primarily in the form of grades and percentages, with the possible inclusion of some comment about effort and behaviour. This, as the section on diploma disease, (section 2.2.12), has highlighted, generally resulted in an institutionalised system of learning to pass, and pass well if possible, where parents, and their children, expressed a preference for class time to be devoted to teaching *the answers* rather than developing knowledge and wisdom. The whole 'grinds' industry is based on this philosophy, where it could be argued that acquisitional learning, rather than the Vygotskian learning-and-development dialectic, forms the conceptual framework.

In applying Ryan and Deci's self-determination continuum, (Figure 2.3), to this goal based system, the impetus for learning would be expected to fall within one or more of their four categories of extrinsic motivation, or even within amotivation for those students where the bar had been set too high too frequently and they had become inured with learned helplessness, (section 2.2.4).

The new specification had been designed, as far as was possible, to avoid the goal-based perspective of the previous syllabus by attempting to remove the terminal examination component's primacy, and the focus on recall of factual information. The potential concerns of teachers around assessing their own students' junior cycle performances were taken by the representative teaching unions, prior to consultation, as enough of a change to practice to require a directive to avoid engagement with the draft specification. Potentially valuable contributions from practitioners were isolated from the consultation process by this, as the discussions of the draft specification at Dublin Castle on the 14th October 2014 were then, by union order, limited to those, like the author, who were not under union instruction. Demands, driven by the unions, however ultimately resulted in the inclusion of a terminal examination, assessed by the State Examination Commission, (SEC). This represented a dilution of the original intent for junior cycle science. More significantly, the idea of developing a course with motivation to engage as the driving force was superseded by one that has an examination as its ultimate assessment. It will be interesting to see how this impacts on meaningful learning strategies, but it might be anticipated that diploma disease will continue to cloud the experience of junior cycle science for some time yet, as the leaving certificate programme, and tertiary education, is still largely examination performance focussed. This could result in a continued expectation from parents, expressed through the interests of their children, that junior cycle should provide a fact-based preparation for the leaving certificate rather than be a programme for developing scientific literacy, and the metacognitive and key skills required to effectively manage their own learning.

The purposes of this research are to introduce flipped-mastery learning through the use of student action cycles, (SACs), and evaluate any impact this might have on student engagement with junior cycle science. The conceptual framework that is the basis for the design of the SACs has at its heart the author's beliefs that intrinsic motivation may be the most powerful effector in terms of student engagement, that emergence of skills and their application with context lead development, and that learning and development cannot be extricated from one another.

As already discussed, (section 2.2.4), intrinsic motivation drives engagement through interest, enjoyment and satisfaction, where the individual feels a sense of relatedness to others, while remaining autonomous and in control. To extend deCharms analogy, the student is empowered to become 'the Queen' of their own chess game rather than 'a pawn' in someone else's.

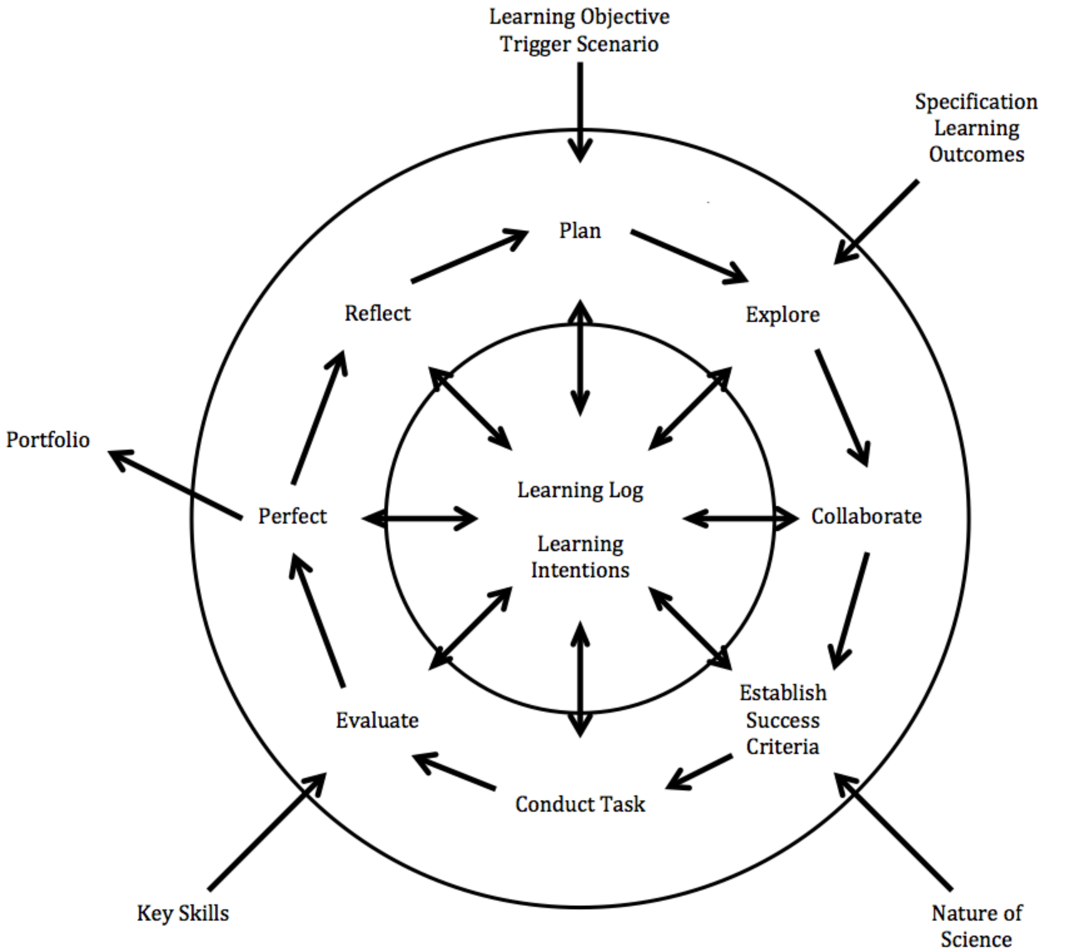


Figure 2.19 The structure of Student Action Cycles (SACs), outlining the intended learning and metacognitive processes

The diagram above, (Figure 2.19), describes the structure of student action cycles, designed by the author after careful consideration of various theoretical aspects of the literature review. The following explains how the diagram integrates with theory.

A learning objective trigger scenario is the initiation stage of any particular student action cycle. These are fashioned to provide specific curiosity, (section 2.2.11), about a situation that is somewhat familiar, but where a question, problem or challenge is presented that requires a re-evaluation, or reorganisation, of current knowledge and a search for new information; essentially providing interest and excitement within Day's "Zone of curiosity" (Figure 2.7). The scenarios have a framework such that students are not overwhelmed by the research opportunities that they present, which might then lead to a loss of confidence in their ability to engage with the task. The use of concept cartoons, (section 2.5.2), in some cases, as trigger scenarios will help to ensure that prior learning and conceptualisation are taken into consideration, as well as providing opportunities for metacognition.

Once the scenario has been set, and a problem identified, students enter the planning stage of the cycle. Here, perceptions of autonomy, an essential feature of self-determination theory, (section 2.2.5), are intended to be engendered; though scaffolding may be required for students who might feel initially that they lack competence to engage productively with the task. This planning phase gives, as far as is practicable, control of the direction of the activity to the student with the intention of bolstering learner empowerment, (section 2.2.8), and self-efficacy, within Vygotsky's zone of proximal development, (ZPD); where learning leads development. Active, conscious, volitional engagement by the student at this stage might be the predominant source of motivation. There is a contrast between the philosophies of Piaget and Vygotsky here, where for the former, motivation drives learning, and for the latter, students must learn to become motivated.

The explore component of SACs allows students to address aspects of the key skills, 'managing information and thinking' and 'being creative', to develop inquiry skills and also engage with the learning outcomes from the 'nature of science' strand of the specification. By allowing students the freedom to explore the trigger scenario, the intention is to provide opportunities for empowerment, and to maintain perceptions of autonomy with an internal locus of control; further supporting self-determination theory. An additional extrinsic motivational drive may be the knowledge that, during the collaboration stage that follows, students will be expected to engage with their peers, and work may be completed to avoid appearing unable or lazy by their classmates; epitomised by Maslow's esteem need, (section 2.2.2).

After students have led the direction of their inquiry through the first two stages, they enter possibly the most important phase of the SACs, the stage where they collaborate by sharing their ideas and their findings. Motivational drives during this stage might be internal, external or a combination of both. From an internal perspective, aspects of self-efficacy and self-worth theory, (section 2.2.8), are likely to come into play for the students that have been successful in locating material that is valued by the group as a whole; whether this is openly shared or just confirmed through its mention by others. On an external level, peer approval or praise supports the relatedness component of self-determination theory, which in itself ties to Maslow's love and esteem needs. The use of language to communicate ideas in this collaboration phase is intended to be more than just a case of relaying findings but instead to bring thinking-and-speaking together in a Vygotskian manner such that:

> Speech does not merely serve as the expression of developed thought. Thought is restructured as it is transformed into speech. Thought is not expressed but completed in the word
>
> (Vygotsky, 1987, p251)

The collaborate stage also relates to Vygotsky's zone of proximal development, (ZPD), where the learning-and-development of the group is developed within the zone collectively, and also for the individual where:

> Every function in the child's cultural development appears twice: first, on the social level and later, on the individual level; first *between* people (*interpsychological*), and then *inside* the child (*intrapsychological*)
>
> (Vygotsky, 1978, p.57 italics in the original)

Talk Lessons, (section 2.5.3), although not integrated within the structure of the SACs, are intended to assist in developing the collaborative and cooperative exploratory talk that is essential for this stage.

Establishing success criteria allows for further engagement with the key skills; in particular, 'managing myself', 'staying well', 'managing information & thinking', 'working with others' and 'being creative'. From a motivational perspective it allows students to set targets that are achievable with effort, possibly with guidance, and that will be conducive to flow, (section 2.2.9), when they move on to the 'conduct task' and 'perfect' phases of the SACs. This also allows for differentiation within the group based on the cognitive ability, (section 2.3.2), and the mindset of the students within each group.

The evaluate stage of each cycle is important in that it provides an opportunity to formally reflect on progress against the success criteria, and even to redefine these, before moving on to perfect material that may form part of the student portfolio of work. Once again, opportunities to develop a number of the key skills are provided within context, rather than as a bolt-on activity. Both the Structure of Observed Learning Outcome, (SOLO), taxonomy, (section 2.4.8), and Strategies for Assessment of Inquiry Learning in Science, (SAILS), (section 2.4.9), instruments will be used at this point in SACs to assist in clarifying the students' visions of their product.

In the reflect stage of each cycle, which is intended to be more than an evaluation of the work produced, each student will engage with their peers, and the teacher, either verbally or in writing, thus as Vygotsky put it, completing the thought in word, on the challenges and the successes of the completed cycle, both tool and result. This formalises the learning process by identifying and reinforcing skills, techniques and processes that aided the completion of the cycle and that may be used in subsequent SACs as assessment *as* learning, (A*a*L), (section 2.4.3).

Throughout each action cycle, and integral to it, is the learning log where students record details of their planning and progress through the stages. This is intended to act as a metacognitive, reflective tool to illustrate learning-and development over time within a Vygotskian framework.

The three central pillars of the *Thinking Science,* (CASE), program, (section 2.3.4), namely cognitive conflict, social construction and metacognition, are central to the process of SACs. The trigger scenarios provide the cognitive conflict through careful juxtapositioning of incomplete and, on the surface, incompatible information such that, according to Piagetian cognitive theory, the individual is faced with the task of equilibration to accommodate the new information within schemata. This is to say, the student has to actively construct knowledge rather than passively absorb information. Social construction is evident in every collaborative stage of the cycles. Metacognition, which could be regarded as the *raison d'être* for the SACs and expressed in the key skills of 'managing myself' and 'managing information and thinking', is to be found in the centre of the cycles in the learning log.

Chapter 3: Methodology

3.1 Introduction

The following sections identify the research questions that were the basis for this thesis and detail the rationale for the research techniques chosen to answer them. A brief philosophical discussion of the nature of knowledge follows the section that outlines the positionality of the author and precedes a discussion of the research design, details of the sample group, and also ethical considerations for conducting research with children.

3.2 Positionality

The author commenced his teaching career in 1990 as a member of a large and progressive science department in a high school on the Isle of Wight. This school was one of the first in England to integrate the cognitive acceleration through science education, (CASE), *Thinking Science* materials, (section 2.3.4), into the standard curriculum for all students and to monitor gains in performance as value added. While there, the author was associated with the University of Portsmouth initial teacher-training programme as a subject mentor and was also a tutor for serving teachers in England in the use of ICT to support teaching and learning. In 2002, after crossing the threshold standards for advanced skills teachers, delivering master classes for gifted students, and also modifying the curriculum for those who found the subject particularly challenging, the author moved to Ireland to continue his career.

Teaching in several schools and one of the colleges of further education before taking up his current position gave him a broader experience of the Irish educational system. Extending this experience, the author was a Discover Sensors facilitator, which was a SFI, (Science Foundation Ireland), supported inquiry based teaching and learning education program for teachers of junior certificate science. The focus on inquiry based science education continued as part of the ESTABLISH, (European Science and Technology in Action: Building Links with Industry, Schools and Home) project and then SAILS, (Strategies for Assessment of Inquiry Learning in Science), both coordinated by CASTeL, the centre for the advancement of STEM teaching and learning, in Dublin City University, (DCU). The 'Greener Greens?' project, that is mentioned in this thesis, was developed by the author and won a prestigious award from Science on Stage and is an OSOS, (Open Schools for Open Societies) accelerator module that is used in countries all over the world. The author has made presentations for these projects around Ireland, in Portugal, Greece, France, Hungary and Belgium. He has also presided as a SciFest judge and most recent involvement with CASTeL has been as a practitioner inquirer as part of the 3DIPhE, (Three Dimensions of Inquiry in Pysics Education) program. He has been a lecturer in junior cycle methodologies for the PME, (Professional Masters of Education), students at DCU for the last five years.

Following on from the consultation event for junior cycle science, at Dublin Castle in 2014, the author has worked as a curriculum reform agent for the NCCA, (National Council for Curriculum and Assessment), by developing learning units and from these generating authentic student work for exemplification against success the criteria for junior cycle science. This culminated in a revision of the features of quality for both of the classroom based assessments, (CBA-1 and CBA2), in part as a result of the performances of the author's classes. Work on curriculum reform continues as a member of the leaving certificate development group for the chemistry specification. Other work with the NCCA has included the development of online assessment tools for collaborative learning to be used for PISA, (Programme for International Student Assessment), a worldwide study of students scholastic performance, operated by the OECD, (Organisation for Economic Co-operation and Development).

This history obviously flavours the author's beliefs and practices and influences may be seen in the research design, methods and also might impact on the interpretation of results.

3.3 Research objectives

The purpose of this research was to develop a flipped-mastery model of self-directed, learner-focused interaction with the specification for junior cycle science, (SJCS), (NCCA, 2015), by implementing student action cycles, (SACs), and then to evaluate the effect of this approach with respect to the following questions:

> How closely do specific pedagogical approaches align with students' perceived educational needs and attitudes towards science?
>
> Do student action cycles impact on student collaboration?
>
> Do student action cycles impact on cognitive development?

3.4 Rationale

The discussion that follows briefly outlines the philosophical reasoning behind the selection of a mixed-method research approach with triangulation, founded in the paradigm of pragmatism, by first reviewing some of the ideas that have been expressed about the very nature of social reality, and how it may be investigated.

Ontology is the philosophical study of the nature of reality and has historically been divided into the two opposing and incompatible camps of objective realism and subjective nominalism; the first considering reality to be a pre-existing, external, tangible and measurable entity into which the individual is born and lives without necessarily being conscious of its full extent, while the latter takes the position that experiences are a product of the consciousness of the individual, where names and concepts are artificial creations that are used as tools to structure reality, (Burrell & Morgan, 1979).

Moving from the ontological level of 'what is there to know?' to the epistemological level of 'how we know it', Burrell and Morgan again present the starkly contrasting positions of objectivity and subjectivity under the respective categories of positivism and anti-positivism. They suggest that the manner in which the social world is investigated is predetermined by the epistemological camp to which one belongs.

These are opposing worldviews, or paradigms; defined as "a set of beliefs, values, and assumptions that a community of researchers has in common regarding the nature and conduct of research." (Johnson & Onwuegbuzie, 2004, p.24).

Positivism, as a paradigm, holds that the acquisition of knowledge is a cumulative process best achieved by employing the traditional approaches of the natural sciences, such as developing a testable hypothesis, careful observation and collection of data and then analysis of phenomena to attempt to identify relationships; in essence, a quantitative approach. That an understanding of phenomena involves the interplay between perspicacity, reasoning and research is, in effect, a restatement of the notions expressed two hundred years earlier by Comte, who reinvented positivism in the early 19th century with the idea that knowledge is imposed on the mind by experience, (Mouly, 1978).

Those who subscribe to the anti-positivist paradigm refute the idea that social science can generate any true objective knowledge and instead argue that the frame of reference of the observer in positivism is meaningless as knowledge can only be developed through an understanding achieved through personal experience. Marx and Hegel, for example, who were contemporaries of Comte, proposed that research should instead focus on the analysis of people's interpretations of social actions. This paradigm is also referred to as constructivism.

With regard to human nature, another dichotomy divides those who question whether individuals act with free will from those who argue that responses are predetermined by surroundings. The latter stance, a mechanical, stimulus/response perspective is described by determinism while voluntarism, with self-initiated creativity and the ability of will to override reason to produce one's own reality, encompasses the former.

With ontological and epistemological positions directly impacting on the purist's choice of methodology it is hardly surprising that the 'paradigm wars', (Merton, 1987; Gage, 1989; Johnson & Onwuegbuzie, 2004), that bubbled to a head in the latter part of the last century, divided researchers into one camp or the other.

Individuals with a positivistic, deterministic view of social reality would typically adopt a nomothetic methodology, characterized by its quantitative nature with experimentation, numerical data collection and statistical analysis to establish norms, while researchers of the opposing anti-positivistic, voluntaristic stance were best served with an idiographic methodology, relying on an individualistic, qualitative approach that often focused on participants' observations, analyses of conversations or interviews, and personal constructs.

A third 'cherry-picking' methodology exists though, that embodies pragmatism as its central philosophy. It is the appropriately named mixed-methods approach that, technically is not an alternative paradigm, (although it has been referred to as the pragmatic paradigm), (Onwuegbuzie & Leech, 2005; Morgan, 2007), but instead, draws from the strengths of both by combining qualitative and quantitative approaches to bring about a greater depth of understanding in educational research.
The potential of a mixed-methods methodology was illustrated by Merton, (1987), at the height of the 'paradigm wars', when he identified that on their own, objective and subjective approaches were unlikely to deliver a full and meaningful analysis of any situation. He commented that qualitative tests allowed him and his researchers to determine the aggregate effects of any particular stimulus, but gave no clue about what it was that caused these effects. Qualitative interviews and group discussions provided this insight, but in turn led to further hypotheses about the sources and character of the responses, which then required qualitative analysis to validate.

Opponents to mixed-methods research, the incompatabilists, argue that, as a methodological movement, it lacks a proper foundation within an appropriate paradigm; that is to say, ontologically and epistemologically, it has no parentage.

Howe succinctly summed up the issues in his incompatability thesis by stating that positivist and interpretivist paradigms underlie quantitative and qualitative methods and that as the paradigms are incompatible the methods must be too. He argued that the cart had been put before the horse and advanced:

> an alternative, pragmatic view: that paradigms must demonstrate their worth in terms of how they inform, *and are informed by*, research methods that are successfully employed
>
> (Howe, 1988, p.10, italics in the original)

Onwuegbuzie and Leech, (2005), suggest that because not all quantitative and qualitative methodologies fit into their respective parent domains of positivism and interpretivism these terms to describe methodologies should be replaced by the descriptors confirmatory and exploratory respectively. They go on to propose that a polarized reliance on one methodology to the exclusion of the other may be the biggest threat to the advancement of the social sciences and confirm the view of Tashakkori and Teddlie, (1998), that "all distinctions between quantitative and qualitative research methods lie on a continua." [continuum], (Onwuegbuzie & Leech, 2005, p.384).

Pragmatism, as a 'new' paradigm to replace the old world order of the philosophy of knowledge, encompassing ontology, epistemology and methodology is proposed by Morgan, (2014). He is careful to remind the reader that this approach is a restatement of Dewey's, (1925a, 2008), pragmatic philosophy centred on human experience, where, rather than starting with a metaphysical discussion about the nature of truth and reality, Dewey instead proposed beginning with life experience, with all its contextual, emotional, cultural and social aspects. Dewey saw both the positivist and anti-positivist views as essentially two equally important halves of the whole, as one's experiences of the world are necessarily constrained by its physical nature, and one's understanding of the same comes from personal interpretation.

> Pragmatism, when regarded as an alternative paradigm, sidesteps the contentious issues of truth and reality, accepts, philosophically, that there are singular and multiple realities that are open to empirical inquiry and orients itself toward solving practical problems in the "real world"
>
> (Feilzer, 2010, p.8)

Focusing on human experience, the processes of acquiring knowledge, and the uses to which this is put, can be summed up in Dewey's model of experience that cycled the processes of reflecting on beliefs to choose actions and then reflecting on those actions to chose beliefs.

> Knowledge is not about an abstract relationship between the knower and the known; instead there is an active process of inquiry that creates a continual back-and-forth movement between beliefs and actions.
>
> (Morgan, 2014, p.1049)

Pragmatism then, is the paradigm of choice for the mixed-methods approach to resolving the research questions of this thesis, as they all contain elements that lend themselves to qualitative and quantitative analysis. Triangulation between the qualitative and quantitative data resulting from the use of SACs, responses to various questionnaires, and focus group discussions should help to paint a clearer picture of student perceptions around, and attitudes towards, the research questions.

The structure of the student action cycles, on the other hand, have their basis in action research; by revolving through reflections on beliefs to choose actions and then reflecting on those actions to choose beliefs, in accordance with Dewey's model of experience. This structure is described in the next section.

3.5 The rationale behind student action cycles

The following describes how the foundations of student action cycles, (SACs), lie in action research. To do this, an overview of action research is first provided.

Lewin, widely credited with popularizing the term action research, in reference to social practices, stated that, "research that produces nothing but books will not suffice." (Lewin, 1946, p.35). In the time since making that statement, action research has evolved into a generic term for any research that attempts to improve practice through a dynamic, cyclical process of identifying a problem, initiating remedial action, evaluating the effectiveness of the intervention and progressively developing more effective solutions through repetitions of this cycle. This strategy is quite different from applied research where, as far as is possible, variables are strictly controlled, analysis of results confirms theory, and there is no direct attempt to mitigate or resolve problems, (Cohen & Manion, 1994). That is to say, the transformative nature of action research is incompatible with the traditional, objective, 'scientific' approach of applied research as, in the former, theories are not validated independently and then applied to practice, rather they are validated through practice.

Numerous, similar models have been proposed for the action research process that all contain the basic features of identifying a problem central to the research, proposing a strategy for its resolution, acting on this and observing the outcome before modifying the strategy, as appropriate, and then acting on it again. Examples of these are Stringer's "Action Research Interacting Spiral", (Stringer, 2007, p.9), Bachman's "Action Research Spiral", (Bachman, 2000, p.36), and Riel's "Iterative process of action research", (Riel, 2016), to name a few.

The model selected for the basis of the SACs is Calhoun's "Action Research Cycle" (Figure 3.1), as it contains provision for constant refinement and clarification of tasks, actions, and analysis of the effects of them; in essence, metacognitive feedback loops within each cycle, (shown by the dotted arrows).

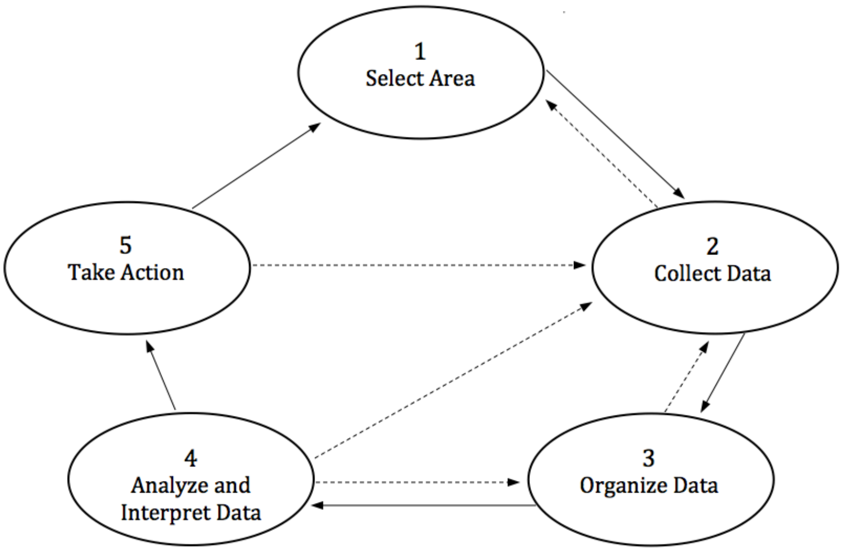


Figure 3.1 The Action Research Cycle, redrawn from the original in How to Use Action Research in the Self-Renewing School by Calhoun, 1994, p.2

Crawford identified action research as "essentially a social process and the knowledge generated through the research process has its origins in human action, interaction and reflection", (1995, p.239).

The SACs are intended to develop "the knowledge, values and capacities of individuals, and their capacities for self-expression, self-development and self-determination", (Kemiss, 2006, p.462), which Kemiss defines as education. Kemiss goes on to separate education from schooling, which he regards as the:

> institutionalized processes and practices established in a society (not only by the state) to prepare individuals to participate in the cultural, social and economic life of the society."
>
> (Kemiss, 2006, p.462)

He regards both schooling and education as essential, “never either, always both”, (p.467), but concludes that:

> We risk giving them schooling at the cost of their education. They are increasingly trained to succeed at tasks set for them by others rather than to pursue their own reasonable aspirations through learning and through becoming educated about the world they live in.
>
> (Kemiss, 2006, p.463)

Kemiss’ self-expression, self-development and self-determination are the driving force behind the SACs where learning is intended to be functional, realistic and relevant. The intention is to empower students, within the very general constraints of learning outcomes from the specification for junior cycle science, (SJCS), (NCCA, 2015), to choose what and how to learn, what to accomplish and how to demonstrate mastery of this; as Costa highlighted, previously there has been a tendency to focus “on learning *of* the objectives, not learning *from* the objectives.” (1981, p31. italics in the original). Collaboration with peers, self-monitoring and personal reflection are integral in the cycles and provide a means of review and for target setting, where not only the subject specific knowledge or skills development are appraised, but also the whole process in terms of what worked well, less well, and what could be done to improve the process. The key skills, (NCCA, 2015, p.7) and ‘Nature of science’, (NCCA, 2015, p.10), are fully embedded at every stage within SACs.

> Teacher directions, focusing, and instructions, therefore, must ensure that students realize thinking processes and strategies are the goals of instruction; that the

responsibility for thinking is the students'; that it is desirable to have more than one solution; that it is commendable when they take time to plan and to think; that it is ok to change an answer with the addition of more information.

(Costa, 1981, p29)

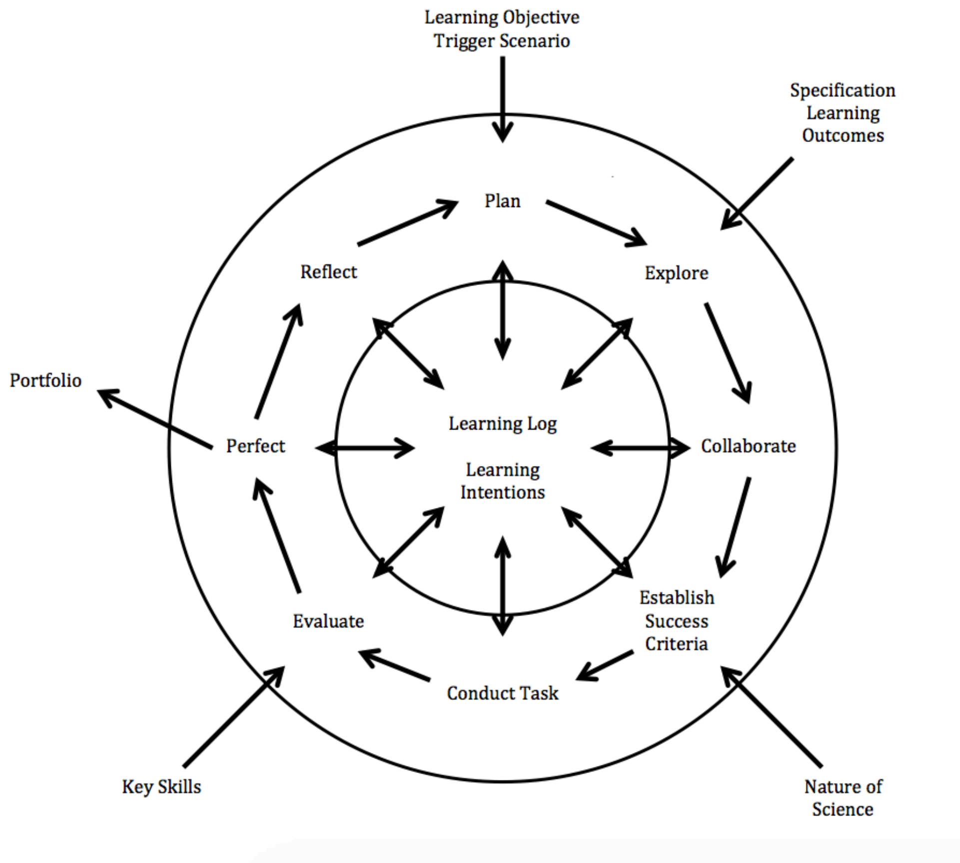


Figure 3.2 The structure of student action cycles (SACs)

The collaborative aspects of the SACs are particularly important as;

Learning would be exceedingly laborious, not to mention hazardous, if people had to rely solely on the effects of their own actions to inform them what to do … from

> observing others one forms an idea of how new behaviors are performed, and on later occasions this coded information serves as a guide for action.
>
> (Bandura, 1977, p.22)

The teacher role in these cycles is as facilitator, mediator or participant; to provide support and encouragement and guidance as appropriate.

> for effective learning to occur, students must construct their own knowledge and teachers must orient their instructional practices towards teaching for understanding. Instead of transmitting knowledge to students, the teacher becomes their guide and helper, assisting students to make their own connections.
>
> (McKeown & Beck, 1999, p.25)

The transfer of knowledge, filling up the cup from the font of all wisdom, should not be the primary function of any educational system; although some could regard the Irish grinds culture, with its focus on rote learning for terminal examinations, to have tended to inculcate such a tradition. It is the breaking of the mould provided by the new framework for junior cycle, (Department of Education and Skills, 2015), the eight key skills of junior cycle, (NCCA, 2012), of being creative, being literate, being numerate, communicating, managing information and thinking, managing myself, staying well and working with others, and the specification for junior cycle science, (SJCS), (NCCA, 2015), that facilitate the move from essentially an autocratic, didactic model to a more democratic, student-centred classroom.

> In the learner dimension: the focus must be on developing students' (a) understanding that they are creative agents with the power of choice (*will*) and (b) metacognitive and cognitive information processing strategies (skill) for meeting personal self-development and self-determination goals. In the learning environment dimension, the focus must be on designing (a) programs that equip significant others (teachers, administrators, parents) with the ability to maintain relationships and quality interactions that create climates of positive socioemotional support; and (b) structures and content that fit the information, self-assessment, and goal needs that facilitate students' positive self-development
>
> (McCombs & Marzano, 1990. p. 63. italics in the original)

3.6 Research instruments

For reasons already outlined in the rationale, both quantitative and qualitative methods were employed to attempt to answer the three research questions:

> How closely do specific pedagogical approaches align with students' perceived educational needs and attitudes towards science?
>
> Do student action cycles impact on student collaboration?
>
> Do student action cycles impact on cognitive development?

The embedded mixed-method approach was employed as it is important to be cognisant that whereas it is relatively easy to empirically test the acquisition of a body of knowledge in a quantitative manner through any variety of recall test instruments, for example, it is only through the qualitative processes of discussion, Vygotsky's thinking-and–speaking and listening, that a student's interpretation of data and internal constructs may be determined. Alternative frameworks and mismatches between the science of the classroom and the nature of the real world are individual to the learner and are often not easily identified through standard testing. The real world is too often perceived as being very distant from, and unconnected to, the body of science answers that a student has been traditionally required to regurgitate for an examination.

Instruments, such as the science reasoning tasks, (SRTs), (Appendix II), and selected statements from the Trends in International Mathematics and Science Study, (TIMSS), were chosen to provide a comparison against external data; although it must be noted that these instruments were designed for specific contexts and that, although they have been rigorously tested, direct comparisons of results between this study and their previous use may not be entirely valid.

The next two sections identify the quantitative and qualitative approaches that were employed, followed by a brief discussion outlining how these were combined to answer specific research questions; thus offsetting the inherent weakness of a reliance on one approach by itself.

3.6.1 Quantitative instruments

The ‘How I feel about school’, (HIFAS), survey

The ‘How I feel about school’ survey, (HIFAS), is a forty-six item five point Likert-scale questionnaire that asks students to respond to various statements regarding their school experience, (Appendix III). It is based in part on the high school version of the learning and study strategies inventory, (LASSI-HS), (https://www.hhpublishing.com/ap/_assessments/LASSI-HS.html), but adapted by the author so that both the language and the spread of statements better matched the focus of this study. Essentially, HIFAS examines student attitudes, behaviours, motivations and beliefs related to their secondary education across the whole curriculum. Distributed throughout it are statements that probe students’ perceptions of resilience and their personal control over learning as well as their attitudes towards learning, goal setting, assessment, feedback, curriculum content and group work.

The Trends in International Mathematics and Science Study, (TIMSS)

The Trends in International Mathematics and Science Study, (TIMSS), is an international survey of mathematics and science achievement, attitudes to learning, features of the home environment, school climate and a range of other factors, investigated through student, teacher and parent multi-statement questionnaires at both primary and secondary level that takes place every four years, and was first implemented in 1995. Only selected TIMSS statements, relating towards attitudes in science were analysed in this study, and compared to recent international data for benchmarking.

Entry/exit ticket surveys

A number of different entry and exit ticket surveys were conducted in this study, providing both quantitative and qualitative data. An example of one of these, was a short, five item five-point Likert-scale questionnaire, (Appendix IV), presented to students after topics were introduced, but before they had begun to engage with them, that asked them to rank their position against the options of “Motivated/Unmotivated”, “Interested/Uninterested”, “Involved/Uninvolved”, “Excited/Bored” or “Dreading it” and “Looking forward to it.

The ‘Intrinsic Motivation Inventory’, (IMI)

The ‘Intrinsic Motivation Inventory’, (IMI), developed by Ryan and Deci (2000), (sections 2.4.4-6), is a multi-statement seven-point Likert-scale questionnaire designed to measure the subjective emotions of interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, perceived choice and relatedness. The first subscale, interest and enjoyment, is regarded as a direct measure of intrinsic or extrinsic motivation. In this study all statements from this subscale were used but the Likert-scale was reduced to provide five options.

Mindset questionnaires

Both Diehl's Mindset Quiz, (DMQ), (Appendix V), and the Dweck Mindset Instrument, (DMI), (Appendix VI), were used to ascertain whether individuals subscribed to a perception of growth or fixed mindset. It is argued that mindset orientation relates to engagement in that it can provide insight into whether students are focused on the quality of their learning, including their skills development, or are more attuned with acquisitional learning-to-pass.

Science reasoning tasks, (SRTs)

Two of the science reasoning tasks, (SRTs), *Volume & heaviness*, and *The pendulum*, developed by Shayer and Adey, (1974), as part of the Concepts in Secondary Mathematics and Science programme, (CSMS), (Appendix II) were used to benchmark students at their respective Piagetian levels, pre-implementation, and to monitor development during their engagement with the new science specification and SACs. Results were compared against those for other students within the same cohort, and from previous years, and also against the wealth of comparative data available from tens of thousands of students worldwide, (Wylam & Shayer, 1978; Shayer, Ginsburg & Coe, 2007; Shayer & Ginsburg, 2009; McCormack, 2009). The intention in applying these instruments was to determine whether the student action cycle process had any impact on cognitive development that was measurable and different from that of students not exposed to them.

The collaboration survey

A collaboration rubric, designed to act as a formative and summative assessment tool, (Appendix VII), based on assessment strategies incorporated into SAILS, (Strategies for Assessment of Inquiry Learning in Science), (section 2.4.9) and material produced by the 21st Century Learning Design partners, (21CLD), (https://www.sri.com/work/projects/21st-century-learning-design-21cld) was used with students in this study. The survey was divided into three sections, namely planning, doing and conclusions, with four statements in each scored on a five-point Likert-scale. This survey also included space for students to add further statements or comments.

3.6.2 Qualitative instruments

The 'How I feel about school', (HIFAS), survey

The 'How I feel about school' survey, (HIFAS), mentioned in the previous section on quantitative instruments, finished with the statement, 'The questions I should have been asked are:' and encouraged students to respond. Comments provided added further insight into students' perceptions around many aspects of their schooling.

Exit tickets

A variety of different entry and exit tickets were used throughout this study to gauge student interests, attitudes and perceptions. For example, as a reflective tool, second year students were given five questions to respond to twice throughout the year. These questions were: “What did you enjoy the most?”, “What was easy?”, “What was hard?”, “What helped you learn most?” and “What did you do when you found something hard or difficult to understand?” The questions were designed to be open-ended to collect as wide a selection of responses as possible, which then provided topics for focus group discussions.

Student focus groups

Students were randomly selected to form focus groups, both from classes using student action cycles, (SACs), and from the rest of the student cohort, and asked to identify areas of the curriculum that they found easiest or most difficult to access. They were asked to make suggestions as to how they felt their learning could be expedited. The information provided by these focus groups was recorded and analysed to assess the perceptions of students in regard to their progress, motivation and enjoyment of the subject. Groups of leaving certificate students were also formed to analyse the perceived difference between the junior cycle and junior certificate examination papers.

Video/audio recordings

The use of video and audio allowed for more thorough and detailed analysis of student engagement with the SACs in conjunction with the other qualitative and quantitative methods outlined. Parts of recordings were replayed with the students to question their reasons for particular actions, or paths of investigation, in order to further consolidate learning and development. In addition to this, the video of 'Greener Greens' that was produced won the prestigious award of national champion for the school for 'Open Schools for Open Societies', (OSOS), and was presented at the event in Cité de l'Espace in Toulouse.

The 'Intelligence' survey

The mindset instruments mentioned, under quantitative instruments, generated several topics of discussion, both in class and in focus groups, revolving around concepts of intelligence. In order to develop a better understanding of students perceptions around this term, which is critical to an understanding of responses to Dweck Mindset Instrument, (DMI), (Appendix V), in particular, students were asked to write brief answers to six short questions. The questions were: "What does the word intelligence mean to you?", "Do you think there are different types of intelligence? - If you said yes, what might they be?", "Who is the most intelligent person you can think of", "What do you think affects how intelligent someone is?" and "Can people change how intelligent they are?"

The student portfolio

The summative, student-selected items that were included in their portfolios also provided an opportunity to evaluate the depth of commitment to self-directed learning.

The Key skills log

Key skills are to be fully integrated within the teaching and learning of the curricula of all subjects on a phased roll-out basis. It is expressly not the purpose to organize stand-alone key skill assessment tasks, but rather to encourage students to monitor their learning and note examples that they regard as exemplary of these competences in a log as a metacognitive tool. It is anticipated that the traditional end of term report structure for parents from school will be modified, in time, to bring it in line with the new framework, and to facilitate this reporting, reference will be made to student identified material from their logs that exemplify their key skills competences. The logs, compiled by students in this study were used to assist in the evaluation of students' metacognitive involvement with their tasks, including the SACs.

> Individual cognitive maps displaying deficiencies and peaks in intellectual abilities should replace test scores. Tests should be learning experiences starting with real and concrete problems and advancing to more abstract, complex tasks. Over time, we should look for evidence of students' increased spontaneous and autonomous use of intelligent behaviors. Thus, the product of assessment should be not what answers the student knows but how the student behaves when he or she doesn't know.
>
> (Costa, 1981, p.31, spelling from original)

3.6 Embedding the instruments

The following sections describe the rationale for and methods in which the various qualitative and quantitative instruments mentioned were combined, with triangulation, to more effectively answer each of the research questions.

3.6.1 Students' needs and attitudes

The initial approach employed to answer the first research question, "How closely do specific pedagogical approaches align with students' perceived educational needs?", involved the construction of a broad-based survey, 'how I feel about school', (HIFAS), to baseline the study on the students' experience rather than on the impression of the author. Even though the design and focus of the questions had been based on an extensive review of relevant literature, it was felt that without the authenticity of the 'student voice' in the process, the responses might have the potential to self-fulfil expectations; thus students were asked to suggest questions that they should have been asked.

Analysis of these first results raised further questions, for example, what was it that led to a noticeable increase in mind wandering or distraction as students progressed through the school? Building on the Relevance of Science Education, (ROSE), report and the Student Review of the Science Curriculum, further surveys containing both quantitative and qualitative elements, the ways of learning questionnaires 1 and 2, were employed.

The picture that emerged from these studies was that the general student experience was of a much more passive role than had been realised by the author. Further qualitative and quantitative studies, including formal and informal discussions, were employed to examine students' perceptions of effective teaching and learning strategies and the use of talk in a sociocultural manner to assist in their development.

Group work had been highlighted on a couple of occasions as a highly effective strategy enjoyed by the majority of the student population; but there were exceptions. A further open ended qualitative survey was used to attempt to establish why there might be variance in responses.

The Trends in International Mathematics and Science Study, (TIMSS), was a fortuitous inclusion, as it allowed for benchmarking against the Irish student population as a whole, but in itself it set up further questions to be explored.

Content and delivery were examined in open-ended studies that asked students to reflect, in a number of ways, on their educational experience, and the mindset instruments, set to establish whether a mental position as to ability limited performance, threw up a series of questions that related to students understanding of and the term intelligence.

Throughout, focus groups provided further clarification of questions that arose from the research, as well as evaluations of teaching strategies and the examination system as a whole.

The output from these combined approaches is detailed in the results section.

3.6.2 Student collaboration

Student collaboration was measured through a rubric presented to students during traditional activities and with student action cycles. The results from this study where primarily quantitative as the question to be answered focussed on changes in levels of collaboration, rather than reasons for these.

3.6.3 Cognitive development

As with the analysis of student collaboration, the impact of student action cycles on cognitive development was analysed in a purely quantitative manner.

3.8 Sample

The research that forms the basis of this thesis was undertaken in a co-educational, multi-cultural, interdenominational, post-primary, ETB (Education and Training Board) school in the north of county Kildare, close to the border with Meath and Dublin. The school has an average population of 780 and draws students from a broad socio-economic base, both within the town and from its surrounding areas. Science is a core subject within the junior cycle program and is allocated three classes of forty minutes per week. All junior cycle students possess Ipads. In the initial year the sample group comprised all first year students, with five classes of these receiving a standard delivery of the curriculum and the remaining two, the student action cycle program. In the second and subsequent years of the study the sample group was extend to include the incoming first year students while still following the initial cohort.

3.9 Ethics

Ethical Approval to conduct this research was awarded by the University of Dublin, Trinity College in June 2014, (Appendix VIII), and by the Board of Management of the Community College, that was the focus of this study, in the same month.

Under Article 12 of the United Nations Convention on the Rights of the Child, (UNCRC), any individual under the age of 18 who is able to form their own views has the right to express them in matters affecting them. This respects the individual's right to autonomy and self-determination.

A document outlining the purpose of the research, and methodologies to be employed during it, was issued to students and parents to enable them to give assent and consent respectively; children under the age of 18 are unable to give legally valid informed consent, which must be obtained from their parents or guardians.

It was particularly important to obtain consent for audio and video recording with a firm assurance of confidentiality and anonymity. Arrangements were put in place such that any parent not wishing their child to be part of the research group was able to have their views respected, and a place in another class would have been allocated if such a request had been received. Parents and students were fully supportive throughout the research and gave full permission for materials produced, and video recorded in class, to be used by both the National Council for Curriculum and Assessment, (NCCA), and the author, for this thesis.

Transfer information from the feeder national schools, including Drumcondra test, entrance exam and working memory assessment results were collected, codified and used to establish a provisional benchmark for student performance. This benchmark was determined by correlating previous years' entrance data with departmental and junior certificate attainment. The data provided by this analysis was also used to moderate any variance between year groups. Periodically, whole year group results were compared to the pre-established performance indicators and the results from the student action cycles, (SACs), groups analysed to see if there was any variance from the norm.

If it had become apparent during the course of the research that the student action cycles had any deleterious effects on learning and the development of skills of an individual or a group, or any other unforeseen issues had arisen that might have impacted adversely on the students' education, the matter would have immediately been raised with management in the school and under their guidance, appropriate remedial action taken. No incentives or compensation were offered to participants.

None of the data collected, such as test scores, comments from interviews or reflections were shared, or otherwise disseminated, to other members of the study group, or anyone else, in a form that would identify the subject. Data was encrypted and kept on a password-protected computer. The audio recordings of interviews, or focus group participation, were placed in a locked file cabinet until a written word-for-word copy of the discussions had been created. As soon as this process was complete, the recordings were erased. To protect confidentiality, the subjects' real names were not used in the written copy of the discussions.

Video of participation in class activities was also encrypted and destroyed after it had been analysed; with the exception of material that was developed with the students to exemplify their work, such as the 'Greener Greens' video. The standard conditions referring to anonymity were still enforced.

Raw data such as individual test scores were retained for the duration of the subjects' time in the junior cycle program, as is standard practice within the school. Other raw data such as that from surveys and questionnaires was designed to be non-sensitive; though measures were taken to ensure that any data relating to performance indicators, opinions or attitudes did not enter the public domain in a manner that could identify a particular student to ensure their right to privacy was maintained. It is appreciated that it is common practice for students to compare test results with their peers and nothing can be done to prevent this. However, in all matters, the researcher actively avoided sharing information derived from one student or group that had not been anonymised with another.

Student efolios were regularly monitored for progress and content and blog comments held for moderation before publication. Students received information and training on the risks associated with web based applications in terms of data protection. Students had all signed the school 'safe internet use policy' and were aware that their product was monitored and that all computer rights would have been revoked if they had breached the terms of this policy.

The researcher, as a teacher, has Garda clearance and in addition has completed Children's Officer training as the National Designated Person for a sports organization. As national secretary for this organization and also as chairman of a local credit union the researcher has also undergone training in data protection and compliance with the relevant acts.

Chapter 4 - Results

4.1 Quantitative Analysis Overview

Statistical analysis was conducted using SPSS 25 software, (IBM, 2018). The alpha value selected for all analyses was a =0.05.

4.2 How I feel about school

The literature review, that established the framework for this study, explored a number of theories regarding motivation in addition to meaningful learning strategies and assessment. How well some of these ideas fit with the perceptions of students in all years was assessed by analysis of responses to statements from a forty-six item five point Likert-scale questionnaire called 'How I feel about school', (HIFAS) (Appendix III); which is loosely based on the high school version, (LASSI-HS), of the learning and study strategies inventory (https://www.hhpublishing.com/ap/_assessments/LASSI-HS.html) Randomly distributed through HIFAS are multiple statements that focused on organismic integration theory, diploma disease, resilience, social constructivism, flow, assessment, feedback, mindset, goals, attitude to learning, creativity, iPad use, learning outcomes and curriculum content. HIFAS attempts to answer the first research question, 'How closely do specific pedagogical approaches align with students' perceived educational needs and attitudes towards science?'.

4.2.1 Organismic integration theory (OIT) and the student experience

The 'How I feel about school', (HIFAS), questionnaire has a number of statements that probe self-perceptions of extrinsic or intrinsic motivation, to which students are requested to identify their congruity with, in terms of 'Not at all like me', 'Not very much like me', 'Somewhat like me', 'Fairly much like me' or 'Very much like me'. Three statements, (2, 8 and 20), are also relevant to this section but will be explored under the heading of diploma disease, (section 4.2.2).

If one examines the self-determination continuum of Ryan and Deci, (Figure 2.3), and takes compliance with external rewards or punishments as characteristic of external regulation, (extrinsic motivation), and interest, enjoyment and inherent satisfaction as features of intrinsic motivation, then it should be possible to establish which of the two motivational positions more frequently drives students to engage with their studies.

There is very little room for autonomy in the statement, "I like to be told what I am expected to learn in class", (11), and students who strongly identify with this could be regarded as extrinsically motivated by the external locus of causality. Responses to this statement were collated for all years of study and the Kruskal-Wallis test, (KWt), was used to compare the results. No evidence of an underlying difference in relation to the responses to this statement was found, ($p=0.229$, $t=5.623$, $df=4$) and consequently the aggregated responses have been used to illustrate the distribution, (Figure 4.2.1).

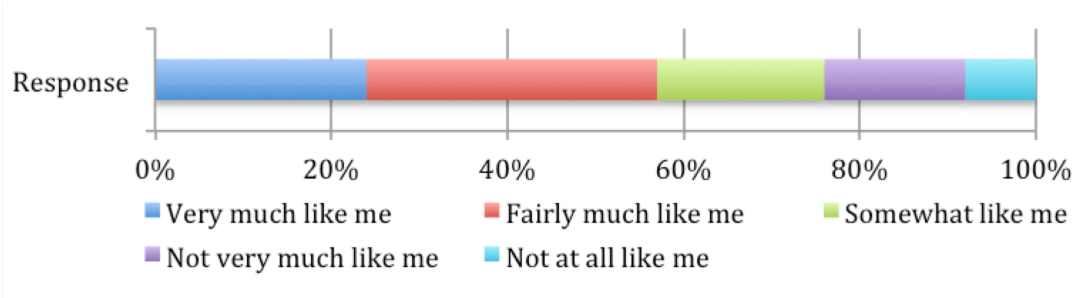


Figure 4.2.1 The distribution of responses, (n=461), to HIFAS statement 11: "I like to be told what I am expected to learn in class."

The group statistics for the analysis are shown below in Table 4.2.1.

Table 4.2.1 Group statistics for the analysis of variance in response to "I like to be told what I am expected to learn in class", (n=461)

Year group	Sample size (n)	Mean rank
1	110	229.61
2	81	210.66
3	86	249.06
5	106	221.10
6	78	247.62

HIFAS statement 25 asks students to position themselves in response to, "I believe that exam success depends more on the teacher I have than on my ability." Affirmative replies again indicate extrinsic motivation, as the locus of causality is identified with the teacher, not the student. No evidence of a difference between year groups was indicated, (p=0.209, t=5.870, df=4) therefore the data, (n=463), was aggregated to produce Figure 4.2.2 below.

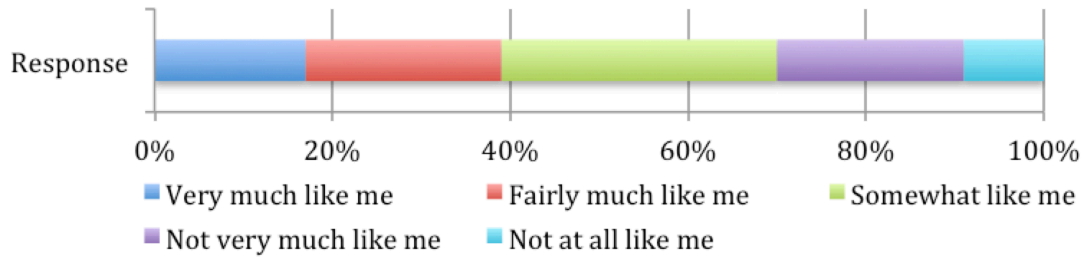


Figure 4.2.2 The distribution of responses, (n=463), to HIFAS statement 25: "I believe that exam success depends more on the teacher I have than on my ability."

Students were asked for their responses to "I often feel I have little control over my learning", (statement 23) and the responses again were found to be fairly uniform across the school community (p=0.471, t=3.547, df=4). The distribution of responses, (n=462), is displayed below in Figure 4.2.3.

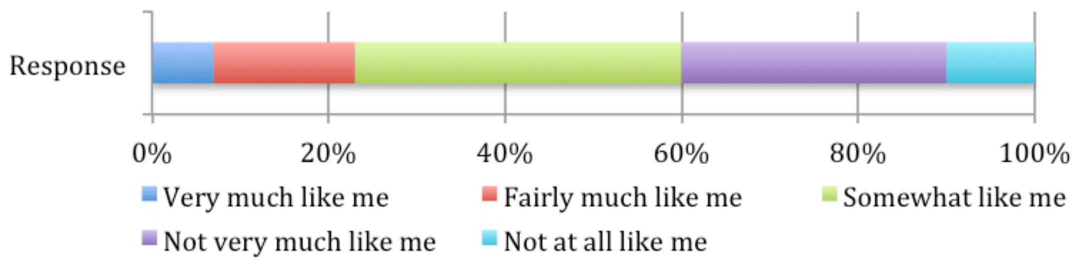


Figure 4.2.3 The distribution of responses, (n=462), to HIFAS statement 23: "I often feel I have little control over my learning."

When students were faced with statement 22, "I often get confused as to what I am expected to learn in class" the responses were again found to be fairly uniform across year groups, (p=0.384, t=4.166, df=4). The aggregated distribution of responses is shown below in Figure 4.2.4.

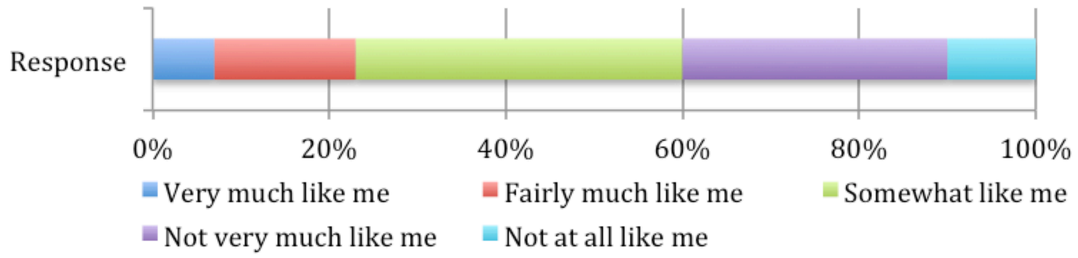


Figure 4.2.4 The distribution of responses, (n=458), to HIFAS statement 22: "I often get confused as to what I am expected to learn in class."

The final statement for analysis in this section is "It is more important to me to impress my teacher or parents by my success in exams compared to learning new skills", (statement 28). Once again there was uniformity throughout the school in the way in which students responded to this, (p=0.104, t=7.685, df=4). The aggregated distribution of responses is shown below in Figure 4.2.5.

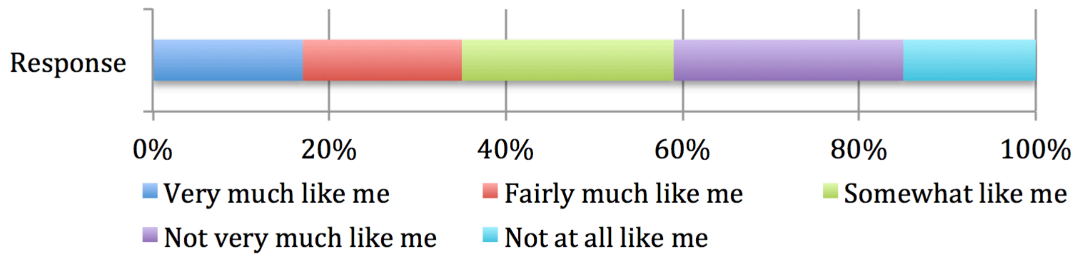


Figure 4.2.5 The distribution of responses, (n=452), to HIFAS statement 28: "It is more important to me to impress my teacher or parents by my success in exams compared to learning new skills."

When weighting was applied to all the responses to the previously statements, (such that "Not at all like me", the intrinsically motivated perception, was given a value of 1 and "Very much like me", the extrinsic position, was valued at 5), a mean score of 2.48 resulted.

Students were encouraged to respond, at the end of the questionnaire, to the statement: "The questions I should have been asked are:". Relevant to ideas around self-determination was the following from a first year students, "Do you like having freedom in your work?", while a sixth year proffered, "Do you believe that learning is independent (i.e. up to you and not a teacher)". Questioning the position of the locus of causality also appeared in this fifth year student's suggestion that, "A teachers ability to teach is reflected within the grades I recieve.",(spelling from original).

4.2.2 Diploma disease and the student experience

Whether or not students identify with the contentions of diploma disease, (section 2.2.12), was examined through analysis of six statements, (2, 8, 16, 20, 35 and 41) in the 'How I feel about school', (HIFAS), questionnaire, (Appendix III).

Students who concur with HIFAS statement 8, "I only want to learn stuff that will come up in exams", should regard school as a place to prepare for exams, and would be expected to choose the option "Very much like me" in support of diploma disease. Responses, (n=462), to the statement were collated for all years of study but, when analysed with the Kruskal-Wallis test, (KWt), no difference was found between them, ($p=0.132$, $t=7.073$, $df=4$). The responses are shown below in Figure 4.2.6.

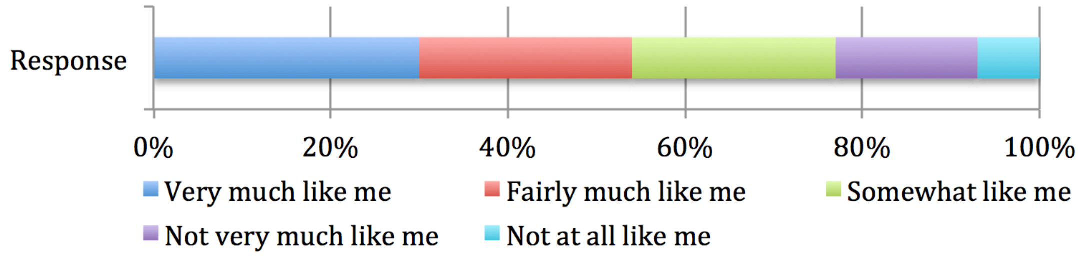


Figure 4.2.6 The distribution of responses, (n=462), to HIFAS statement 8: "I only want to learn stuff that will come up in exams."

The second statement, (20), relating to diploma disease given is, "I prefer tests that ask me to write down facts that I have been told to tests that ask me to work something out". Once again, no difference was found across the year groups, ($p=0.263$, $t=5.251$, $df=4$). A graph of responses can be seen in Figure 4.2.7.

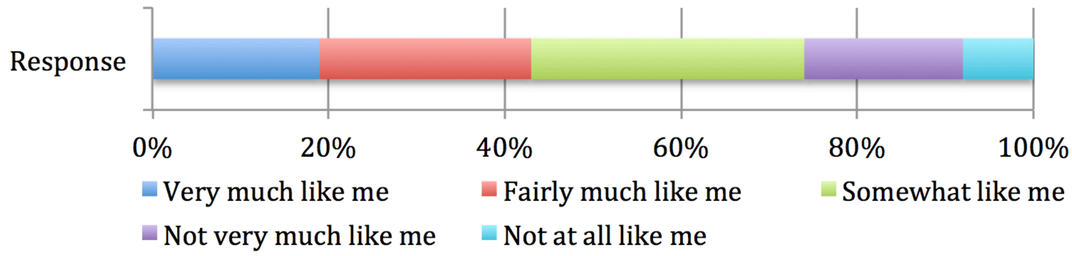


Figure 4.2.7 The distribution of responses, (n=464), to HIFAS statement 20: "I prefer tests that ask me to write down facts that I have been told to tests that ask me to work something out."

The distribution of responses, (n=469), to the statement, (2), "I don't care whether I understand my work as long as I remember enough to get a good mark in tests", was so similar across the school, (p=0.483, t=3.467, df=4) that the combined data has been used to create Figure 4.2.8.

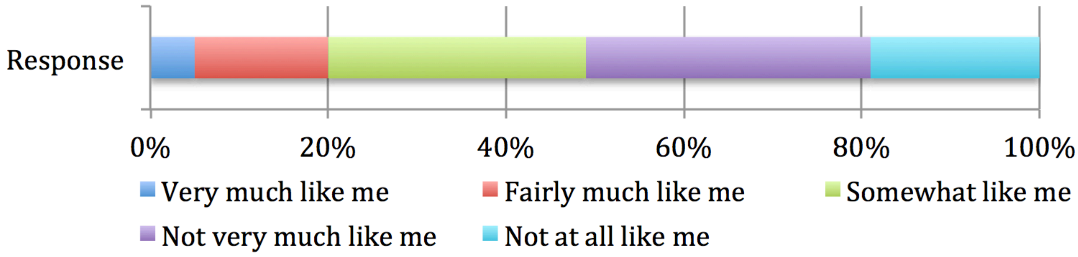


Figure 4.2.8 The distribution of responses, (n=469), to HIFAS statement 2: "I don't care whether I understand my work as long as I remember enough to get a good mark in tests."

Two further statements examine the difference between skills development and rote-learning by first offering students the opportunity to rate their agreement with, "I think it is more important to know the answer than how to work it out.", (16), before reversing the comment to, "I think that learning the skills to solve a problem is more important than knowing the answer.", (35). The responses were assessed for variance between classes and no difference was found for either statement, (HIFAS16 p=0.822, t=1.524, df=4), (HIFAS35 p=0.180, t=6.271, df=4).

The distributions for the categories of concurrence can be seen in Figures 4.2.9 and 4.2.10.

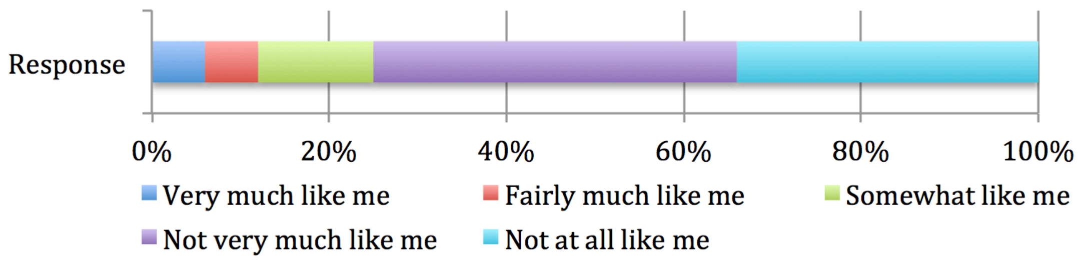


Figure 4.2.9 The distribution of responses, (n=465), to HIFAS statement 16: "I think it is more important to know the answer than how to work it out."

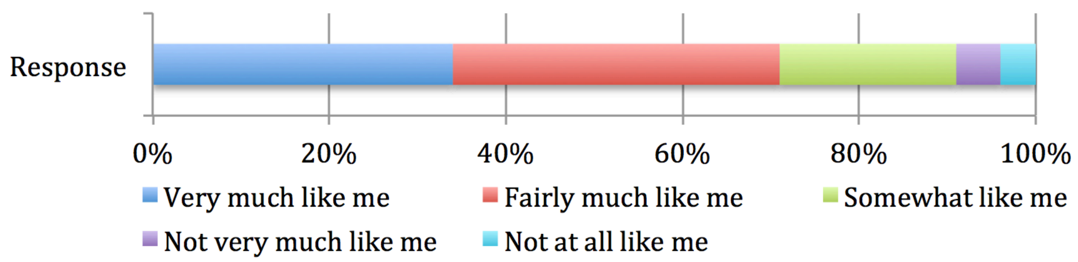


Figure 4.2.10 The distribution of responses, (n=450), to HIFAS statement 35: "I think that learning the skills to solve a problem is more important than knowing the answer."

Finally, students were asked to position themselves with regard to statement 41, "I take what I am being taught at face value without questioning it". The distribution of responses is shown for the school in Figure 4.2.11, ($p=0.093$, $t=7.949$, $df=4$).

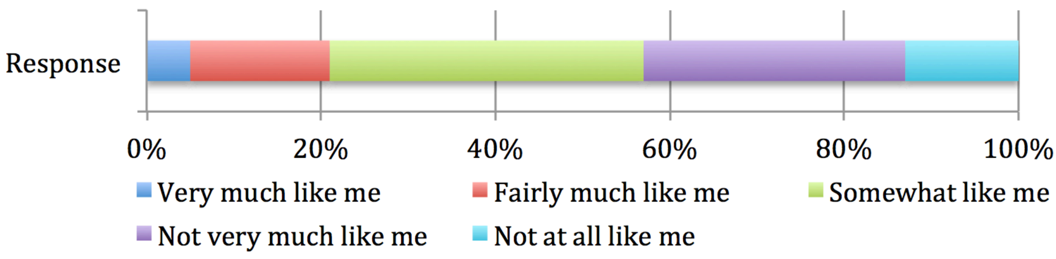


Figure 4.2.11 The distribution of responses, (n=443), to HIFAS statement 41: "I take what I am being taught at face value without questioning it."

When weighting was applied to all the responses to the previously statements, (such that "Not at all like me", equating to learning out of interest, was given a value of 1 and "Very much like me", the diploma disease position, was valued at 5, (reversed for statement 35)), a mean score of 2.71 resulted.

A first year students suggested that the statement, "Do I think I am I being taught what I need to know for my exams?" should have been included, and two others from the same year wrote, "How are you getting on with your tests and practicing for your Christmas exams" and "Why do teachers like exams so much". "Do you feel that there is too much emphasis on exams?", was suggested by a fifth year student and one in sixth year commented:

> School puts way to much emphasis on exams rather than teaching you what you're interested in not the be all and end all of your life like teachers keep stressing it is.

4.2.3 Resilience

Section 2.2.10 of the literature review finishes its exposition on mindset with mention of the need to promote perseverance in the young. The ‘How I feel about school’, (HIFAS), questionnaire contains four statements, (1, 5, 17 and 31), that ask students to position themselves as to how they feel when facing challenges. Individuals who rate themselves in the category “Not at all like me” exhibit confidence and resilience while those who identify with “Very much like me” would tend towards a defeatist attitude.

Statement 17 asks students to respond to “When work gets hard I give up or only study the easy bits”. When the data collected was analysed with the Kruskal-Wallis test, (KWt), no difference was found between second, third, fifth and sixth year students, ($p=0.419$, $t=2.828$, $df=3$), but the first year distribution showed a greater proportion of “Not at all like me” responses, ($p<0.001$, $t=18.907$, $df=1$). The figures from this study indicate that something occurs in the first year of the students’ secondary education that has a large negative effect on resilience, ($r=0.872$). Figure 4.2.12 illustrates the first year response distribution and Figure 4.2.13 the aggregated results for the rest of the school.

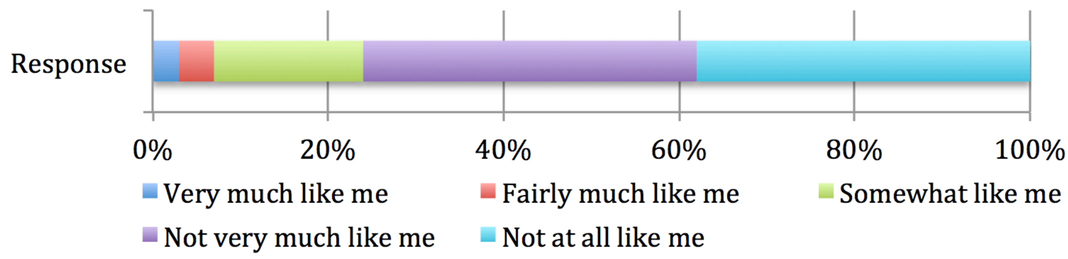


Figure 4.2.12 The distribution of responses, (n=112), to HIFAS statement 17: "When work gets hard I give up or only study the easy bits." for first year students.

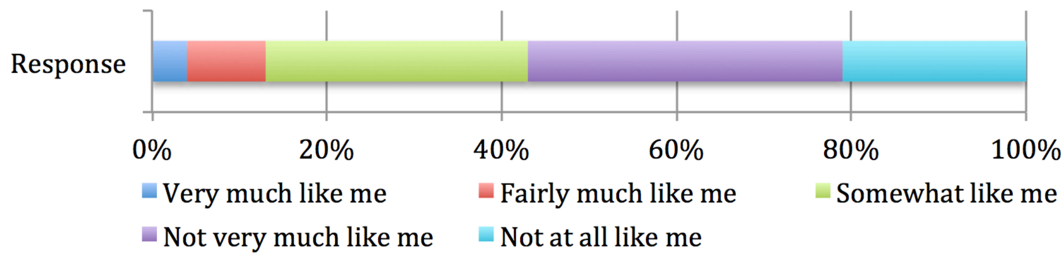


Figure 4.2.13 The distribution of responses, (n=358), to HIFAS statement 17: "When work gets hard I give up or only study the easy bits." for second, third, fifth and sixth year students.

"I get discouraged if I get low marks" is another HIFAS statement, (5), that touches on resilience. The analysis with the KWt revealed no apparent difference between the years, (p=0.061, t=8.999, df=4), and the combined results, (n=466), are shown in Figure 4.2.14.

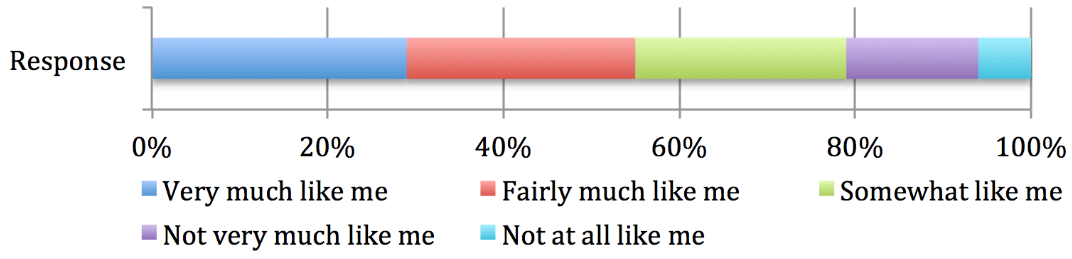


Figure 4.2.14 The distribution of responses, (n=466), to HIFAS statement 5: "I get discouraged if I get low marks."

HIFAS statement 31 states, "Even when I am taking a test that I am prepared for I feel upset". Once again, no difference was found across the year groups, (p=0.728, t=2.043, df=4). The distribution of responses is shown below.

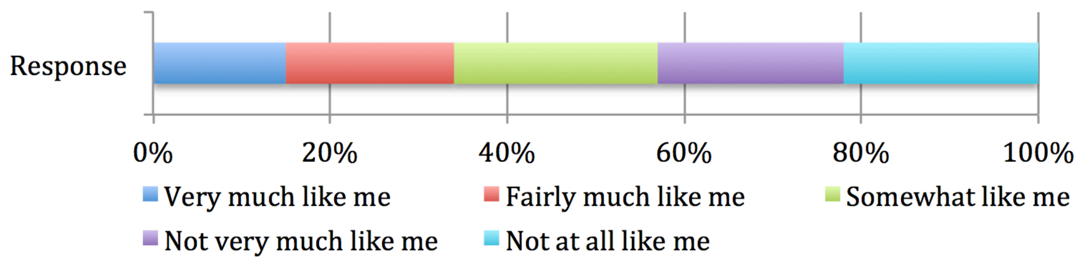


Figure 4.2.15 The distribution of responses, (n=461), to HIFAS statement 31: "Even when I am taking a test that I am prepared for I feel upset."

The final HIFAS statement, (1), included in this section is "I worry that I might fail my classes." As there was no significant difference between years, (p=0.138, t=6.962, df=4), the results, (n=469), have been combined to create Figure 4.2.16.

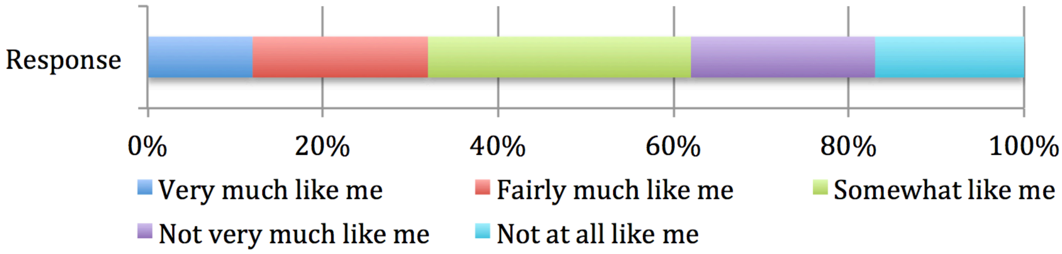


Figure 4.2.16 The distribution of responses, (n=469), to HIFAS statement 1: "I worry that I might fail my classes."

When the results from first year to HIFAS statement 17 are removed and weighting is applied to all other responses, (such that "Not at all like me", indicating resilience, is given a value of 1 and "Very much like me", the defeatist position, is valued at 5, a mean score of 2.34 results.

First year students suggested that, "Do you sometimes fell overwellemed by the amount of work + pressure", and, "Do I feel im succeeding at school?", should have been included, while a third year suggested, "Does Junior Cert Serve any Point but to Stress Students", (spelling from original)

4.2.4 Flow

Section 2.2.9 of the literature review describes Csíkszentmihályi's flow theory. A number of statements in the 'How I feel about school' survey, (HIFAS), probe students' perceptions as to how pervasive flow activities are within their educational experience; these were also supported by responses to short surveys on concentration and distraction.

Two statements in HIFAS examine teacher-talk and student attention. The first of these, (3), asks students to identify their position with regard to, “I find that when my teachers are talking I think of other things and don’t really listen to what is being said”. Responses from first to fifth year showed little difference, ($p= 0.090$, $t=6.489$, $df=4$), but sixth year student were in greater agreement with the statement than the rest of the school, ($p<0.001$, $t=21.169$, $df=1$). The decline in attention span for students as they enter their final year of study was large, ($r=0.980$). The distributions for the school up to sixth year and then for sixth year alone are shown in the next two diagrams for comparison.

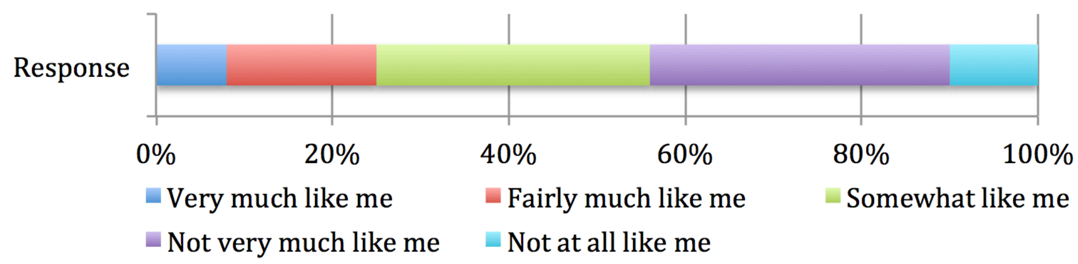


Figure 4.2.17 The distribution of responses, (n=390), to HIFAS statement 3: “I find that when my teachers are talking I think of other things and don’t really listen to what is being said.” for all students except sixth year.

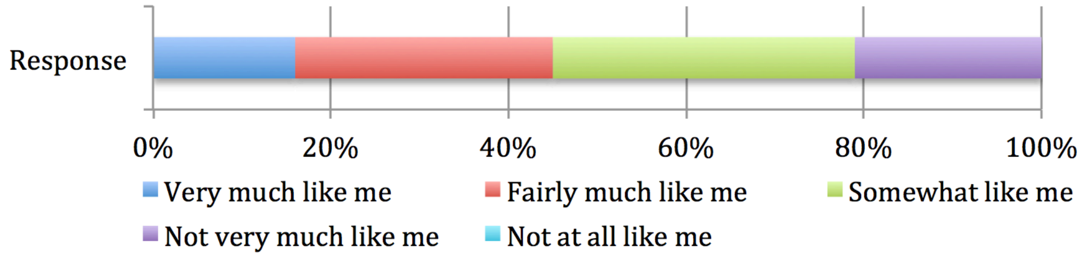


Figure 4.2.18 The distribution of responses, (n=77), to HIFAS statement 3: "I find that when my teachers are talking I think of other things and don't really listen to what is being said." for sixth year students.

HIFAS statement 13 is, "I don't understand some stuff from lessons because I don't always listen to my teachers." The distribution of responses from year groups one to five, (n= 385), were similar, (p=0.168, t=5.055, df=3), so they have been combined to form Figure 4.2.19 to compare with the sixth year results, (n=79), (p=0.007, t=13.955, df=4), in Figure 4.2.20. Whatever it is that affects sixth year students' attention to their teachers was again large, (r=0.417).

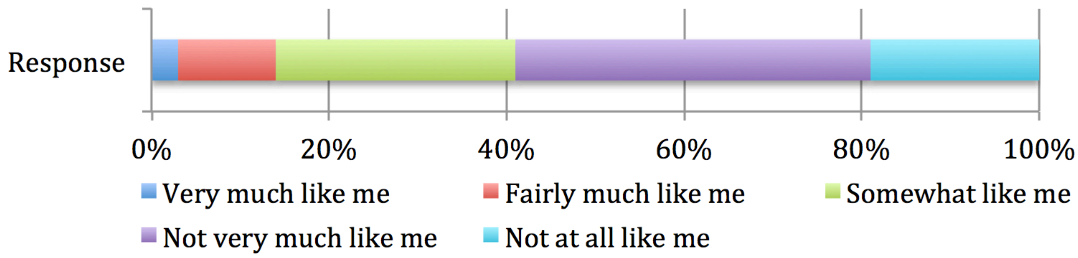


Figure 4.2.19 The distribution of responses, (n=385), to HIFAS statement 13: "I don't understand some stuff from lessons because I don't always listen to my teachers." for all students except sixth year.

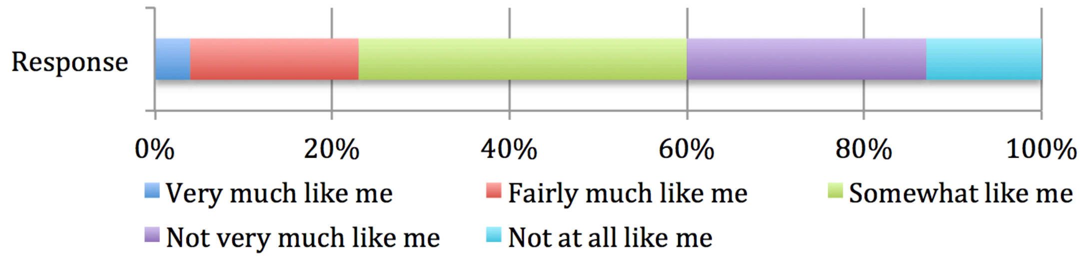


Figure 4.2.20 The distribution of responses, (n=79), to HIFAS statement 13: "I don't understand some stuff from lessons because I don't always listen to my teachers." for sixth year students.

Three HIFAS statements address focus on work. The first of these states, "My mind wanders a lot when I am doing schoolwork". The distribution of responses was very different across the school, ($p<0.001$, $t=20.372$, $df=4$). First year students showed greater focus than that of other year groups while second, third and fifth year students reported a very similar profile, ($p=0.500$, $t=1.386$, $df=2$). Sixth year students were the least focussed. The relationship between year group and increased mind wandering was relatively small between first year and the following three years, ($r=0.448$), and also between the grouping of second to fifth year students when compared to sixth year, ($r=0.314$). However, when the responses from first year were compared directly with sixth year the effect was large, ($r=1.287$). The distributions for first year and sixth year flank those for the rest of the school in the three figures below, and the group statistics are displayed in Table 4.2.2 that follows.

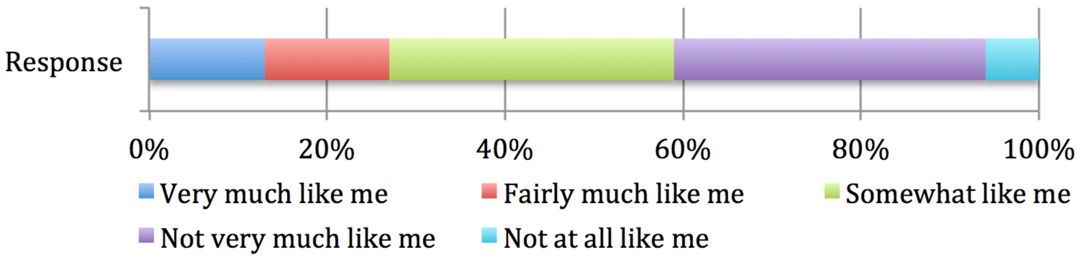


Figure 4.2.21 The distribution of responses, (n=111), to HIFAS statement 9: "My mind wanders a lot when I am doing schoolwork." for first year students.

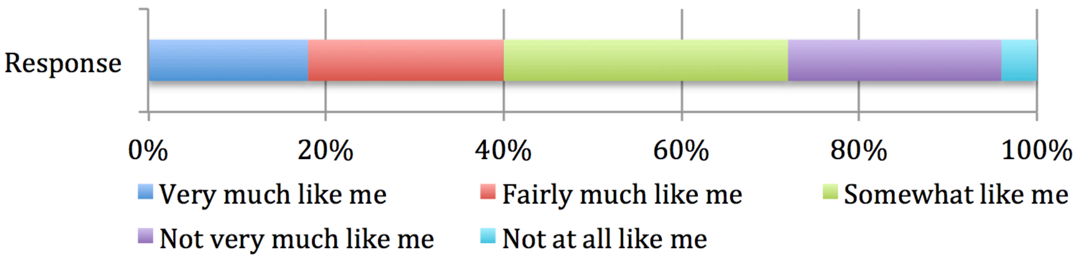


Figure 4.2.22 The distribution of responses, (n=277), to HIFAS statement 9: "My mind wanders a lot when I am doing schoolwork." for second, third and fifth year students.

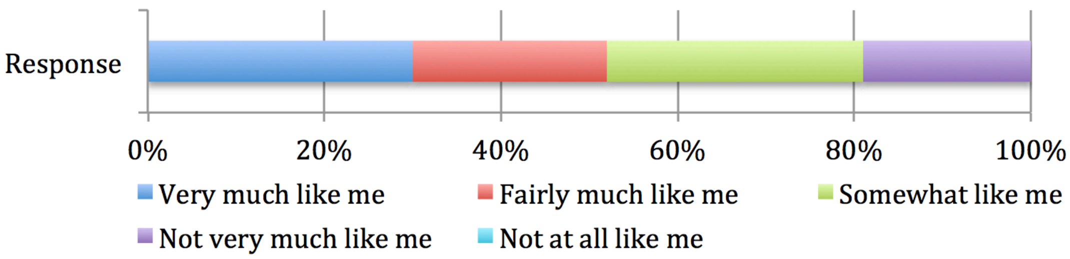


Figure 4.2.23 The distribution of responses, (n=76), to HIFAS statement 9: "My mind wanders a lot when I am doing schoolwork." for sixth year students.

Table 4.2.2 Group statistics for the analysis of variance in response to "My mind wanders a lot when I am doing schoolwork.", (n=464)

Year group	Sample size (n)	Mean rank
1	111	193.39
2	83	223.62
3	87	235.80
5	107	246.15
6	76	276.32

Further on in the HIFAS survey, students are presented with a variation on the previous theme in, "I am not easily distracted from work", (19). The distribution of responses, was similar to the previous statement, and showed a pattern that was very different across the school, (p=0.009, t=13.462, df=4). First year students showed greater focus than that of other year groups while second, third and fifth year students reported a very similar profile, (p=0.379, t=1.940, df=2). Sixth year students were the least focussed. The relationship between year group and increased ease of distraction was relatively small between first year and the following three years, (r=0.215), and also between the grouping of second to fifth year students when compared to sixth year, (r=0.224). However, when the responses from first year were compared directly with sixth year the effect was large, (r=0.852). The distributions for first year and sixth year flank those for the rest of the school in the following three figures and the group statistics are shown in Table 4.2.3.

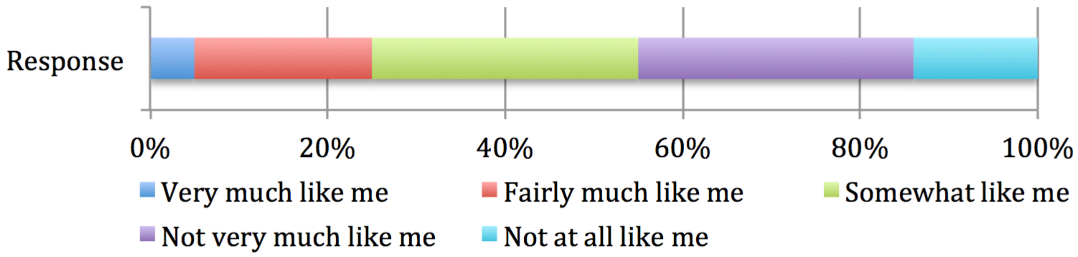


Figure 4.2.24 The distribution of responses, (n=111), to HIFAS statement 19: "I am not easily distracted from work." for first year students.

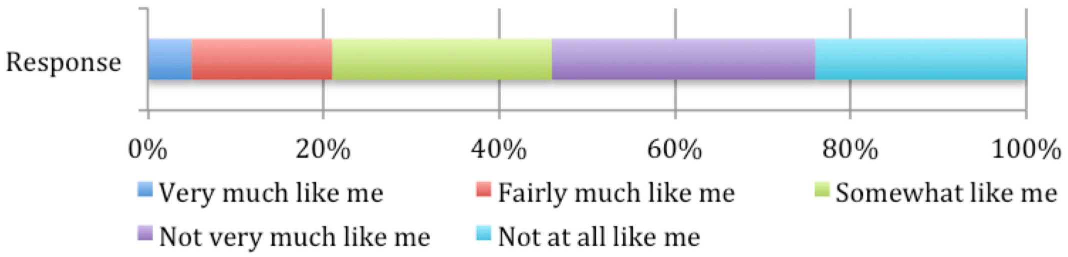


Figure 4.2.25 The distribution of responses, (n=276), to HIFAS statement 19: "I am not easily distracted from work." for second, third and fifth year students.

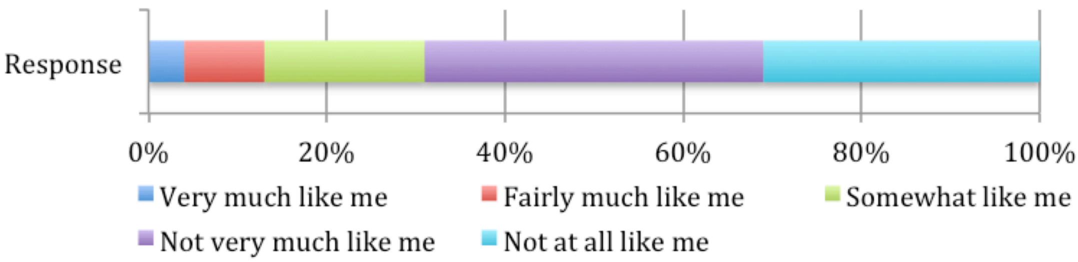


Figure 4.2.26 The distribution of responses, (n=77), to HIFAS statement 19: "I am not easily distracted from work." for sixth year students.

Table 4.2.3 Group statistics for the analysis of variance in response to "I am not easily distracted from work.", (n=464)

Year group	Sample size (n)	Mean rank
1	111	261.29
2	82	223.59
3	87	244.29
5	107	218.21
6	77	196.38

In support of HIFAS statements 9 and 19, students were asked, in a separate open survey, to consider circumstances that promoted mind wandering and increased ease of distraction. For both of the attention disruptions students were asked to identify 'things', 'subjects' or 'circumstances' that they felt were the greatest affecters. The tabulated responses are displayed on the next page, (Table 4.2.4).

Table 4.2.4 The percentage breakdown for different student identified affecters in relation to loss of concentration or ease of distraction, (n=324)

Items that make me:	lose concentration (%)	distracted (%)
Boring work/boredom	18	16
Friends	10	19
Fatigue	4	2
Phone/device	9	21
Hunger	9	3
Overwork/teacher going on	13	2
Home/social life/sports	15	2
Noise	8	29
Anxiety/stress/difficulty	8	2
Weather/temperature/smell of food	3	1
Time of day	1	1
Random things	2	2

The last statement, (46), on the HIFAS questionnaire is "When I am working I don't notice time passing." The distribution of responses was similar across all the year groups, (p=0.064, t=7.248, df=4), and represented in Figure 4.2.27 below.

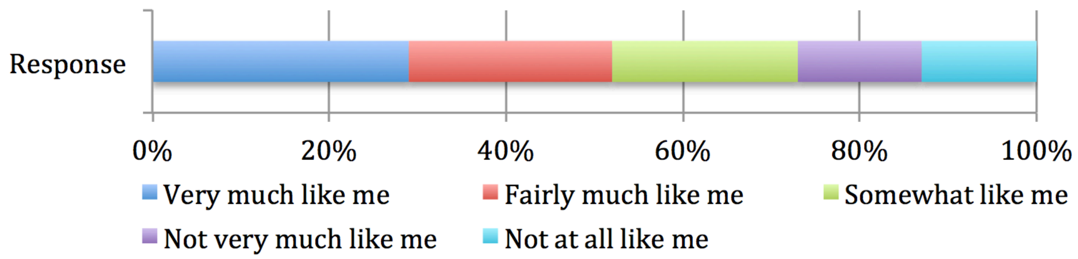


Figure 4.2.27 The distribution of responses, (n=447), to HIFAS statement 46: "When I am working I don't notice time passing."

Two statements in HIFAS focus on challenge, which is essential for flow, and these are, "I like challenges that are difficult and require me to work hard to solve", (26) and, "I like to be given challenging problems to solve", (38). When the distribution of responses for students in different year groups was analysed, no difference was found for the first, (n=463), (p=0.811, t=1.588, df=4), or the second statement, (n=450), (p=0.186, t=4.818, df=4), or between the two, (p=0.647, t=0.201, df=1). The percentage of students identifying with each of the five categories was mirrored for the two statements and therefore a single graph has been used to represent them.

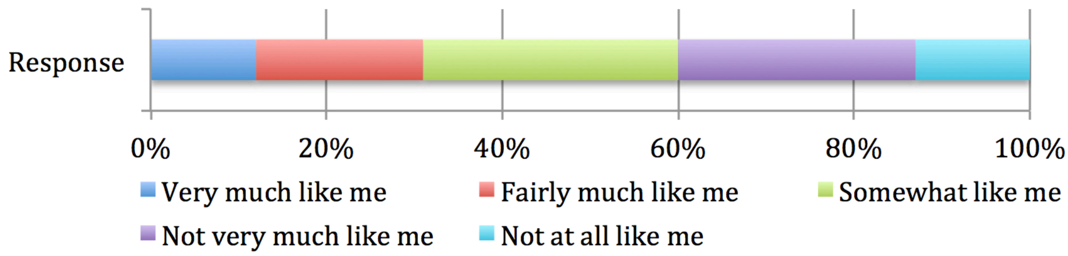


Figure 4.2.28 The distribution of responses to HIFAS statement 26, (n=463), "I like challenges that are difficult and require me to work hard to solve." and HIFAS statement 38, (n=450), "I like to be given challenging problems to solve",

4.2.5 Social constructivism

Classroom conversation that supports Vygotsky's position that thought is completed in the word is discussed in the literature review, (section 2.5.3), and framework, (section 2.6), and forms a major component of student action cycles, (SACs). How students value opportunities to co-construct their learning is addressed by four statements, (4, 14, 30 and 34), in the 'How I feel about school', (HIFAS), questionnaire. Students are asked to position themselves between the extremes of "Not at all like me" and "Very much like me" on a five-point Likert-scale.

The first statement, (4), presents students with, "I find it easier to understand new ideas if I talk them through with my friends." There was no evidence of a difference in responses between the year groups, (p=0.521, Kruskal Wallis H=3.224, df=4), and so the aggregated results are presented in Figure 4.2.29 below.

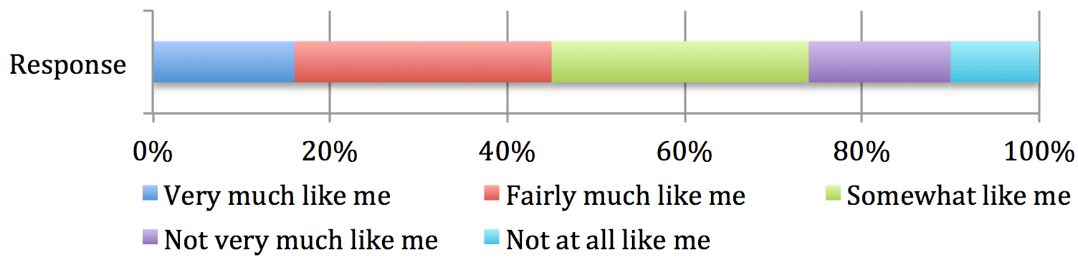


Figure 4.2.29 The distribution of responses to HIFAS statement 4, (n=471), "I find it easier to understand new ideas if I talk them through with my friends."

A further statement, (34), looks at word-and-thought by asking the students', (n=467), position on, "The best classes are the ones where I can learn by talking rather than learn by listening." No difference between year groups' responses was observed, (p=0.830, Kruskal Wallis H=1.478, df=4). The distribution of responses follows.

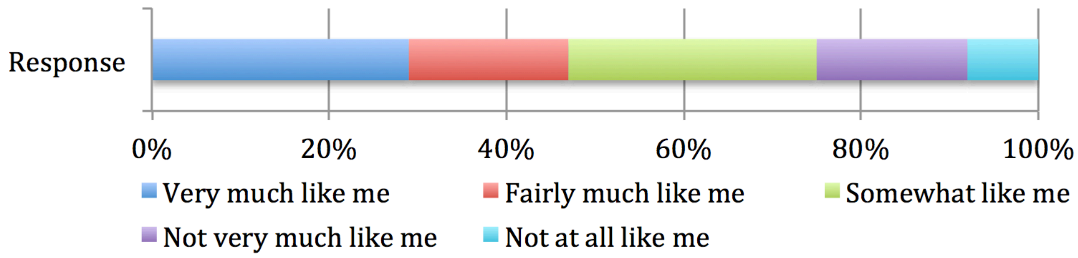


Figure 4.2.30 The distribution of responses to HIFAS statement 34, (n=467), "The best classes are the ones where I can learn by talking rather than learn by listening."

Two statements address sharing ideas. The first, (14), offers, "I prefer classes where I can share and compare ideas with my friends." Interestingly, when the distribution of responses was analysed, both exam years, (n=164), were similar in that 32% disagreed with the idea, (p=0.950, t=0.004, df=1), whereas this dropped to 20% for first, second and fifth year students, (294), (p=0.076, t=5.156, df=2). Although these two distributions are noticeably different, (p=0.009, t=6.777, df=1), as figures 4.2.31 and 4.2.32 show, the effect of impending examinations on the preference for sharing ideas was found to be moderately weak, (r=0.317).

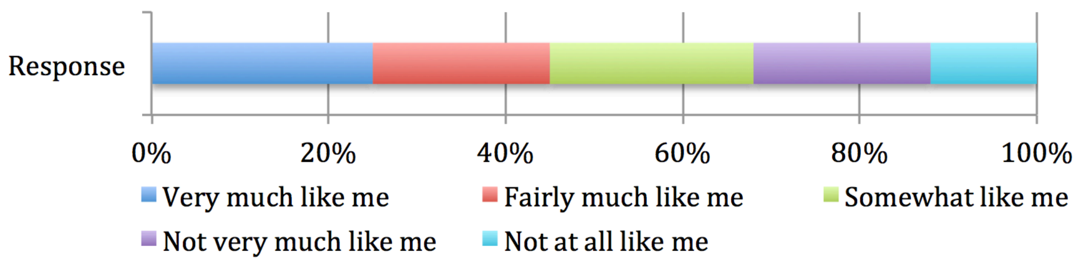


Figure 4.2.31 The distribution of responses to HIFAS statement 14, (n=164), "I prefer classes where I can share and compare ideas with my friends." for third and sixth year students.

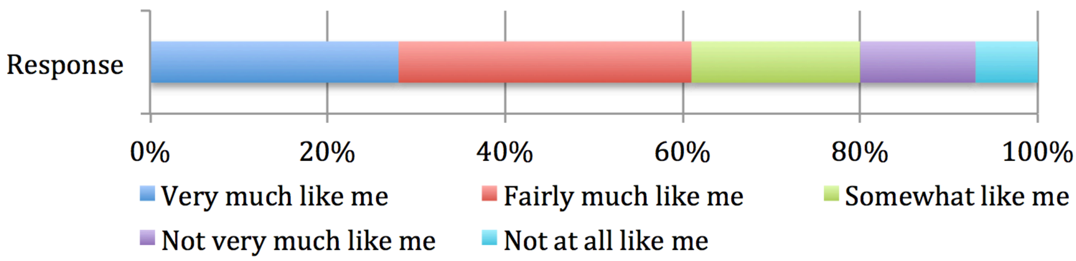


Figure 4.2.32 The distribution of responses to HIFAS statement 14, (n=294), "I prefer classes where I can share and compare ideas with my friends." for first, second and fifth year students.

Table 4.2.5 Group statistics for the analysis of variance in response to "I prefer classes where I can share and compare ideas with my friends.", (n=448)

Year group	Sample size (n)	Mean rank
1	107	247.71
2	83	259.00
3	86	208.18
5	104	220.25
6	78	208.97

The second statement, (30), that explores the students' views on sharing ideas is, "I don't like to share ideas because others might not agree with me." When the distribution of responses, (n=462), was analysed it was found to be uniform across the year groups, (p=0.957, t=0.656, df=4). The results are shown in Figure 4.2.33.

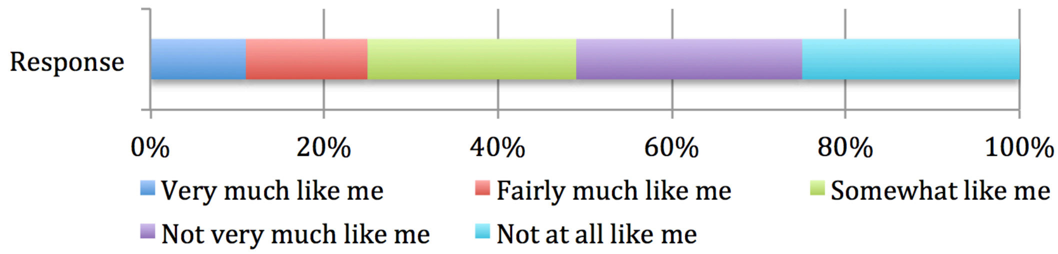


Figure 4.2.33 The distribution of responses to HIFAS statement 30, (n=462), "I don't like to share ideas because others might not agree with me."

When weighting is applied to the responses to the previous statements, (such that "Not at all like me" is give a value of 1 and "Very much like me" is valued at 5, with statement 30 is reversed), a mean score of 3.39 results.

Only one suggestion for a missing statement was offered and this came from a fifth year students who wrote, "I find it easier to work alone than with a group".

4.2.6 Assessment and feedback

Section 2.4 of the literature review discusses both assessment and feedback and informs the conceptual framework for this study. Three statements on the 'How I feel about school', (HIFAS), survey, (6, 32 and 37), were set to examine students' opinions based on responses to a five-point Likert-scale with opposing positions of "Not at all like me" and "Very much like me".

The first of these, (32), asks students to position themselves in relation to, "I think the only way a teacher can know how I am doing is by giving me tests." Responses, (n=464), showed no difference, (p= 0.006, t=14.447, df=4), in their distribution when analysed with the Kruskal-Wallis test, (KWt).

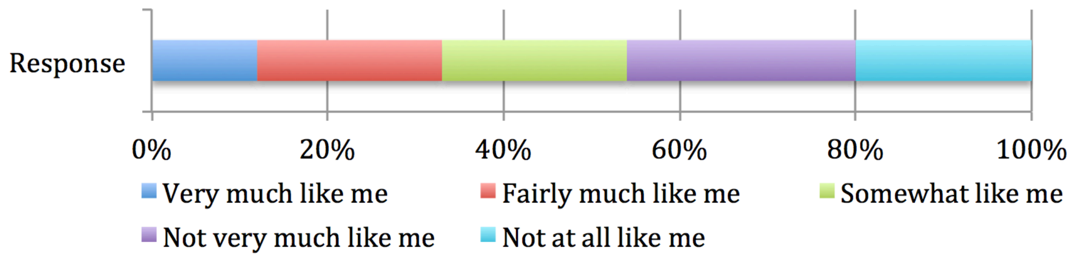


Figure 4.2.34 The distribution of responses to HIFAS statement 32, (n=464), "I think the only way a teacher can know how I am doing is by giving me tests."

"I would prefer to show my skills and understanding by project work to taking exams" is a further statement, (37), on the topic of assessment explored by HIFAS. The distribution of responses, (n=445), was uniform, (p=0.601, t=2.745, df=4), across the school and is illustrated below.

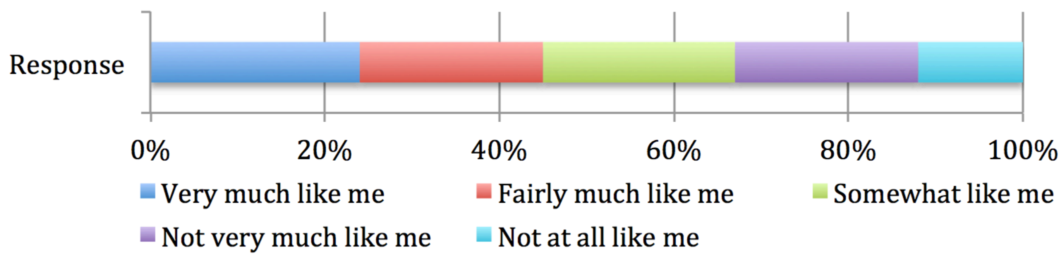


Figure 4.2.35 The distribution of responses to HIFAS statement 37, (n=445), "I would prefer to show my skills and understanding by project work to taking exams."

Tied to the previous statement, in terms of feedback, is the preference for comments or grades. The HIFAS statement, (6), presented students, (n=463), with, "I prefer comments that show me how to improve over grades." The distribution of responses across the year groups was moderately uniform, (p=0.117, t=7.390, df=4), and is illustrated below.

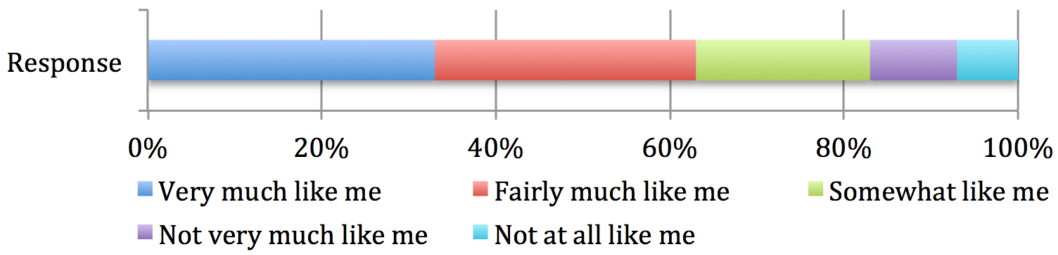


Figure 4.2.36 The distribution of responses to HIFAS statement 6, (n=463), "I prefer comments that show me how to improve over grades."

Additional statements from fifth year students included, "Does frequent testing in subjects help you know how well you are doing?" and, "Do you think homework helps to learn a subject. Do you think frequent tests are useful." Also from fifth year came, "I prefer getting critisized directly rather than with a lot of prays", while a sixth year student wrote, "Do you approve of continuous assessment?", (spelling from original).

4.2.7 <u>Self-regulation and goal setting</u>

In section 2.4 of the literature review, a number of references are made to research that has been conducted into student self-regulation; such as the Learning How to

Learn, (LH2L), project. The extent to which students from this study relate to the concept of learning autonomy, (LA), was examined by the analysis of responses to six statements in the 'How I feel about school', (HIFAS), survey, (7, 18, 42, 43, 44 and 45).

Two statements in HIFAS ask for responses to goal setting behaviour. These are, "I often set goals for myself", (43), and, "I set high standards or goals for myself with schoolwork.", (18). The distribution of responses, (n=454), for the first statement, (p=0.376, t=4.226, df=4), and second, (n=449), (p=0.700, t=2.195, df=4) were pretty uniform across the year groups and also between the two statements, (p=0.262, t=1.259, df=1). The spread of responses is illustrated below in Figure 4.2.37.

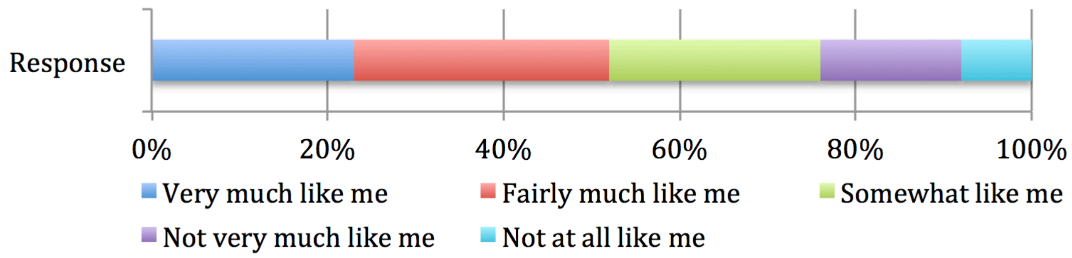


Figure 4.2.37 The distribution of responses to HIFAS statements 18, (n=449), "I often set goals for myself", and 43, (n=454), "I set high standards or goals for myself with schoolwork.

Monitoring progress and managing workload were examined by presenting students with, "I am up to date with all my schoolwork", (7). When the distribution of responses, (n=463), was analysed a clear difference appeared as students progressed through the school, (p<0.001, t=32.799, df=4). First and second year students, (n=194), reported most positively and their distributions were fairly similar, (p=0.703, t=0.145, df=1). Third and fifth year students, (n=192), were also similar in their distribution, (p=0.977, t=0.001, df=1), with sixth year students, (n=77), reporting that they were least up to date with schoolwork. The increase in work backlog resulting from transitioning from first and second year into third and fifth was larger, (r=0.861), than the increase going in to sixth year, (r=0.342). Comparing first and second year student responses directly with sixth year showed a large increase, (r=0.795). The distribution patterns for first and second, third and fifth and sixth year students are shown in the following figures, and Table 4.2.6 presents the group statistics.

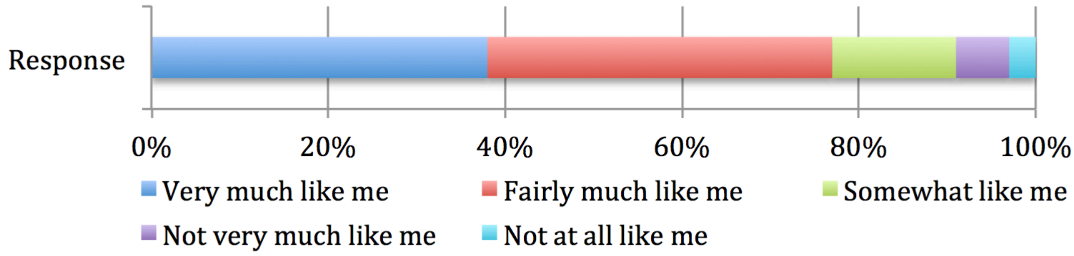


Figure 4.2.38 The distribution of responses to HIFAS statements 7, (n=194), "I am up to date with all my schoolwork" for first and second year students.

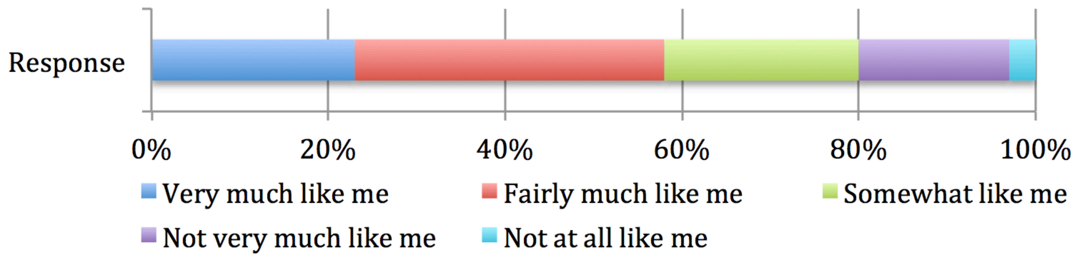


Figure 4.2.39 The distribution of responses to HIFAS statements 7, (n=192), "I am up to date with all my schoolwork" for third and fifth year students.

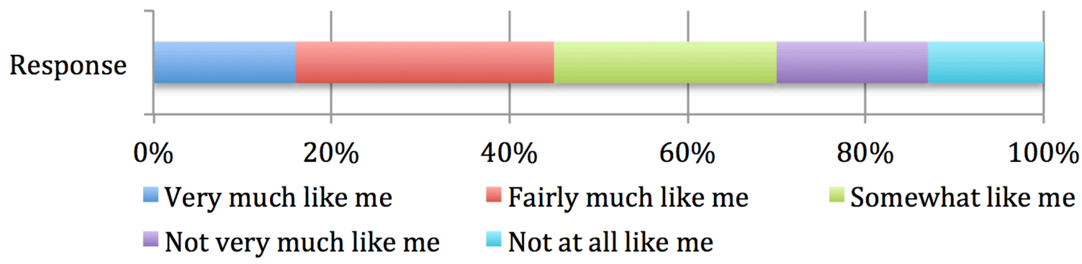


Figure 4.2.40 The distribution of responses to HIFAS statements 7, (n=77), "I am up to date with all my schoolwork" for sixth year students.

Table 4.2.6 Group statistics for the analysis of variance in response to "I am up to date with all my schoolwork", (n=463)

Year group	Sample size (n)	Mean rank
1	111	265.76
2	83	273.34
3	86	217.38
5	106	215.65
6	77	177.60

A sixth year student took the opportunity to voice an opinion in the section, 'The questions I should have been asked are:' with:

> In exam years homework should not be compulsory. The amount of homework I have to complete makes it hard to have study time.

Two statements in HIFAS explore metacognition. They are, "I reflect on my learning to help me improve.", (44) and, "I find it easy to know whether or not I have learned what I am supposed to.", (42). In regard to the first statement, (44), the distribution of responses across the year groups, (n=441), was divided by those who were less inclined to do so and those that were more positive, (p=0.047, t=9.620, df=4). Non-exam year students, (n=289), (p=0.555, t=1.177, df=2), reported that they reflected on their learning more frequently than those in third and sixth year, (n=152), (p=0.935, t=0.007, df=1). The effect on reflection in both exam years was found to be large, (r=0.783). The distribution of responses, and the group statistics, from both of these groups are shown below.

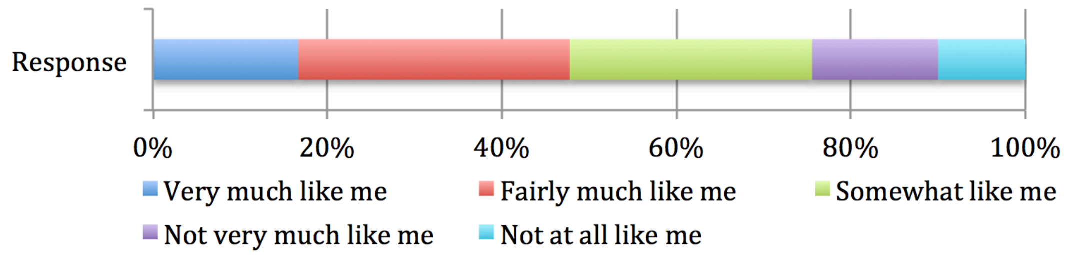


Figure 4.2.41 The distribution of responses to HIFAS statements 44, (n=289), "I reflect on my learning to help me improve.", for first, second and fifth year students.

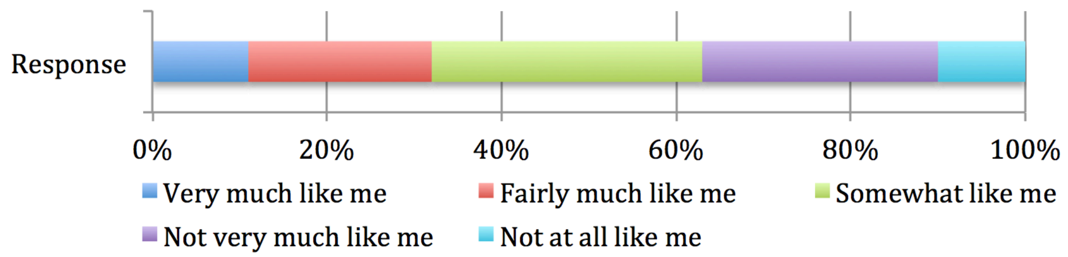


Figure 4.2.42 The distribution of responses to HIFAS statements 44, (n=152), "I reflect on my learning to help me improve.", for third and sixth year students.

Table 4.2.7 Group statistics for the analysis of variance in response to "I reflect on my learning to help me improve", (n=441)

Year group	Sample size (n)	Mean rank
1	104	243.58
2	79	229.22
3	80	197.32
5	106	226.56
6	72	197.49

The second statement examining metacognition, (42), is far more introspective in that it asks students to position themselves with regard to, "I find it easy to know whether or not I have learned what I am supposed to." When responses, (n=444), were analysed, students were found to form two distinct groups, (p=0.011, t=13.087, df=4). First and second year students' responses were very similar, (p=0.862, t=0.030, df=1), and showed them to be much more confident in assessing their learning, (r=0.611), than the rest of the school, where there was a similar pattern of distribution, (p=0.909, t=0.191, df=2), across the other three year groups. This is illustrated on the next page.

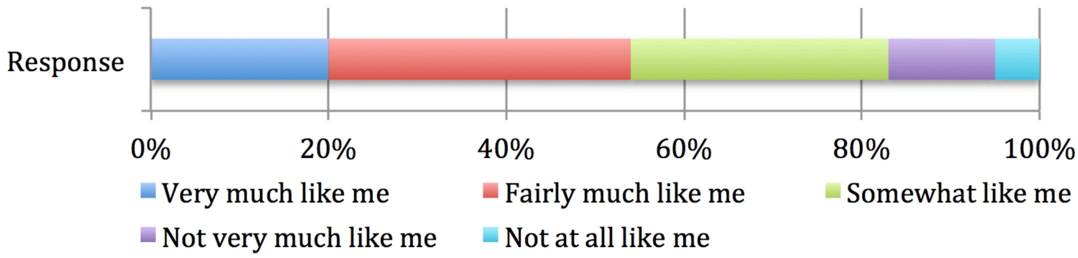


Figure 4.2.43 The distribution of responses to HIFAS statements 42, (n=184), "I find it easy to know whether or not I have learned what I am supposed to.", for first and second year students.

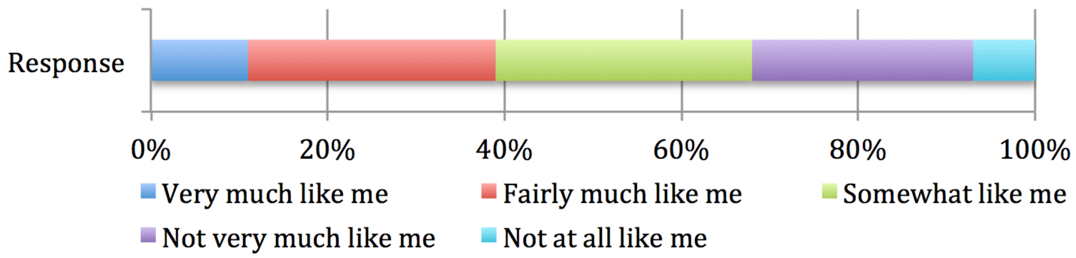


Figure 4.2.44 The distribution of responses to HIFAS statements 42, (n=260), "I find it easy to know whether or not I have learned what I am supposed to.", for third, fifth and sixth year students.

Table 4.2.8 Group statistics for the analysis of variance in response to "I find it easy to know whether or not I have learned what I am supposed to", (n=444)

Year group	Sample size (n)	Mean rank
1	104	248.26
2	80	246.81
3	80	209.26
5	106	204.32
6	74	200.38

The final HIFAS statement, (45), in this section relates to acting on feedback and asks students to consider, “I like the opportunity to redo work to make it better.” The distribution of responses, (n=448), (p=0.016, t=12.162, df=4), was interesting in that third year students, (n=82) were more enthusiastic, (r=0.440), than the rest of the school combined, (n=366), (p=0.404, t=2.923, df=3). The averaged percentage of students from first, second, fifth and sixth year, who expressed a preference for the opportunity to redo work to improve it was 72% as opposed to 86% in third year. Figure 4.2.45 and Figure 4.2.46 illustrate the distribution of responses.

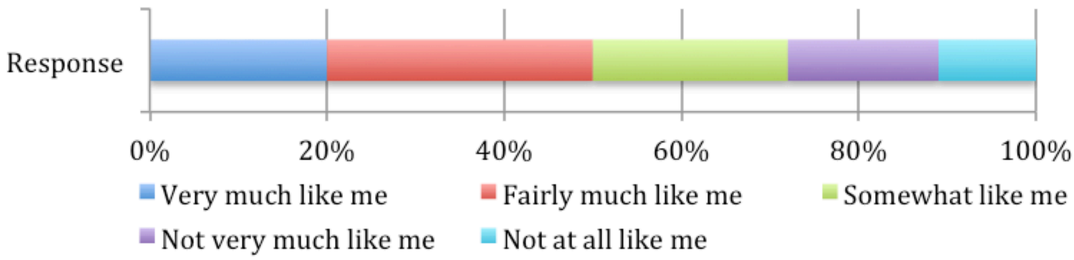


Figure 4.2.45 The distribution of responses to HIFAS statements 45, (n=366), “I like the opportunity to redo work to make it better.”, for all but third year students.

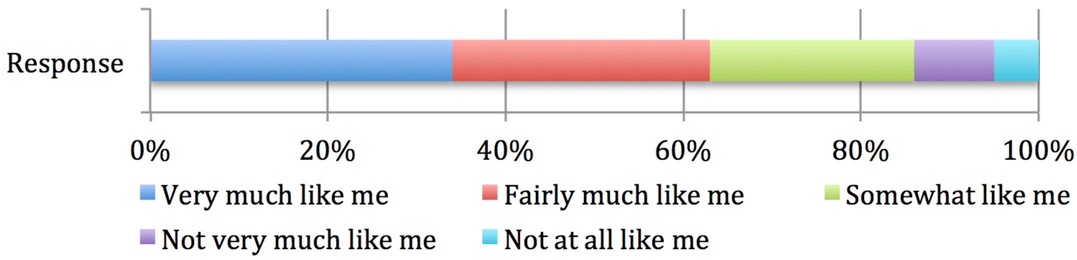


Figure 4.2.46 The distribution of responses to HIFAS statements 45, (n=82), “I like the opportunity to redo work to make it better.”, for third year students.

Table 4.2.9 Group statistics for the analysis of variance in response to "I like the opportunity to redo work to make it better", (n=448)

Year group	Sample size (n)	Mean rank
1	105	229.37
2	79	200.08
3	82	262.87
5	107	219.89
6	75	208.04

In the section of the HIFAS questionnaire for student suggestions the following were recorded. A fifth year student suggested a useful statement would be, "I feel like I understand topics covered in class before moving on". Homework was high on the agenda for two third year students who proffered, "Do you think homework is essential for study?" and, "Do you think the amount of homework you are given is fare?". Finally, a sixth year student felt that, "I feel getting a good grade is worth putting in effort for", should have been included, (spelling from original).

4.2.8 Curriculum content

Section 2.2.13, of the literature review looked at two complementary studies into students' opinions of the science curriculum, these being the Relevance Of Science Education, (ROSE), and the Student Review of the Science Curriculum, (SRSC) projects. In addition, section 2.3 introduced theories about cognitive readiness for meaningful engagement with the curriculum, and the Concepts in Secondary Mathematics and

Science, (CSMS), programme, which looked at matching content to the developmental stage of the student. Two statements in the 'How I feel about school', (HIFAS) survey ask for student opinions on the relevance of content, (27 and 40), one looks into understanding, (39) and a last statement, (15), probes views about creativity. The responses were measured on a five-point Likert-scale with opposing positions of "Not at all like me" and "Very much like me".

HIFAS statement 40 asks for opinions on, "Much of what I learn seems to be unrelated bits and pieces that I can't see the purpose of knowing." When analysing the responses, first year student opinions, (n=106), were very different from the rest of the school, (p=0.007, t=13.955, df=4), in that they were less in agreement with the statement than older students, (r=0.965), where there was homogeneity in their views, (n=341), (p=0.635, t=1.709, df=3). The figures below represent the findings.

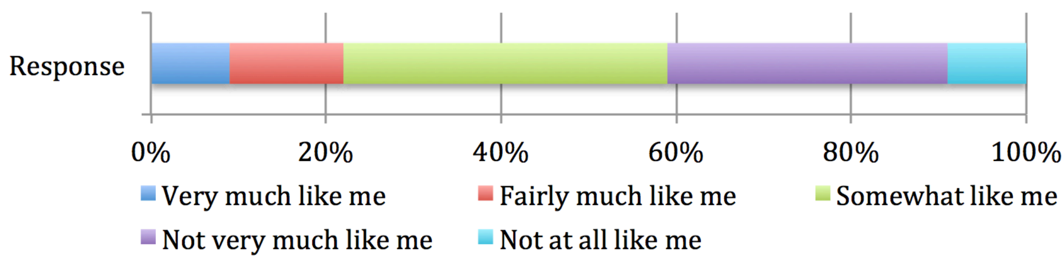


Figure 4.2.47 The distribution of responses to HIFAS statements 40, (n=106), "Much of what I learn seems to be unrelated bits and pieces that I can't see the purpose of knowing." for first year students.

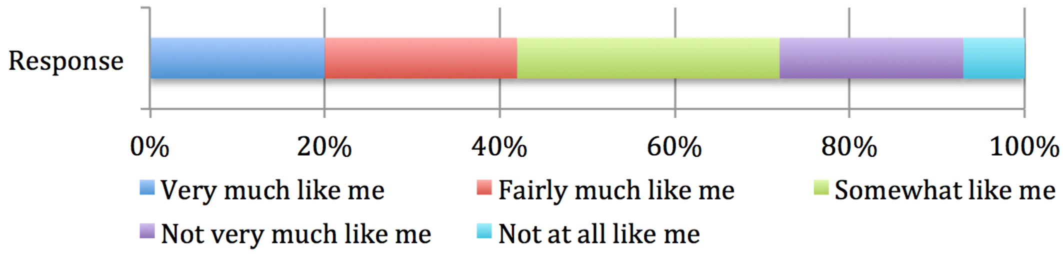


Figure 4.2.48 The distribution of responses to HIFAS statements 40, (n=341), "Much of what I learn seems to be unrelated bits and pieces that I can't see the purpose of knowing." for second, third, fifth and sixth year students.

Table 4.2.10 Group statistics for the analysis of variance in response to "Much of what I learn seems to be unrelated bits and pieces that I can't see the purpose of knowing.", (n=447)

Year group	Sample size (n)	Mean rank
1	106	186.71
2	79	236.56
3	81	234.22
5	107	225.82
6	74	250.18

In support of the previous statement, another that the students were asked to engage with was, "In my opinion, most of what is taught in class is not worth learning.",(27). As with the previous statement, there was a large difference between the distribution of responses from first year students, (n=111), when compared to the rest of the school, ($p<0.001$, $t=35.405$, $df=4$). Second, third, fifth and sixth year students, (n=349), showed a very similar pattern, (p=0.284, t=3.800, df=3), being much more in agreement, (r=1.484). The following figures display the responses for both groups.

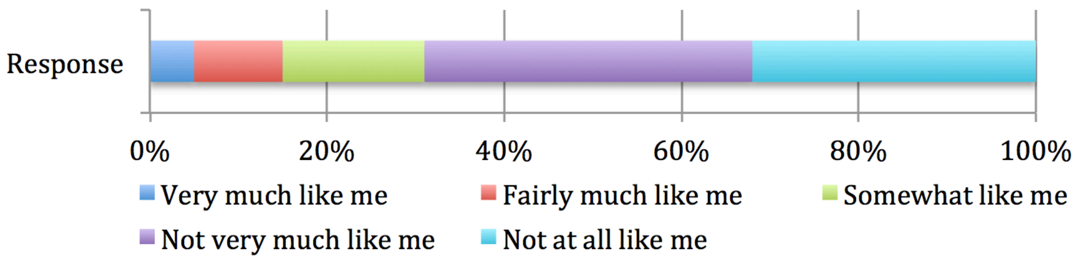


Figure 4.2.49 The distribution of responses to HIFAS statements 27, (n=111), "In my opinion, most of what is taught in class is not worth learning." for first year students.

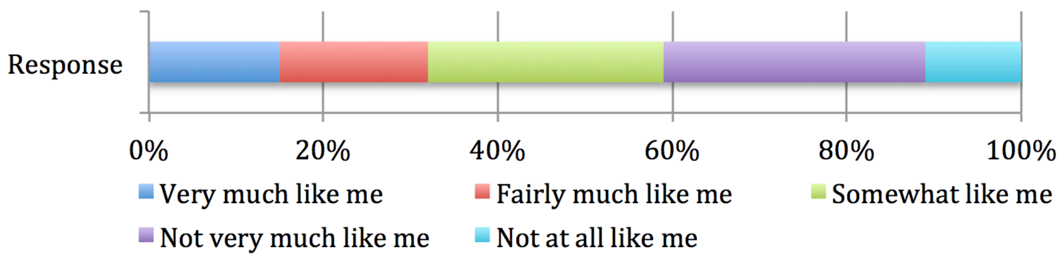


Figure 4.2.50 The distribution of responses to HIFAS statements 27, (n=349), "In my opinion, most of what is taught in class is not worth learning." for second, third, fifth and sixth year students.

Table 4.2.11 Group statistics for the analysis of variance in response to "In my opinion, most of what is taught in class is not worth learning.", (n=460)

Year group	Sample size (n)	Mean rank
1	111	170.23
2	81	227.70
3	86	256.74
5	106	250.22
6	76	264.32

Relatedness and understanding, tying in to an appreciation of learning outcomes, was investigated with, "I often have trouble making sense of things I have to remember.", (39). Student responses, (450), across the school were fairly uniform in their distribution, (p=0.429, t=3.836, df=4). The averaged distribution of responses is shown below.

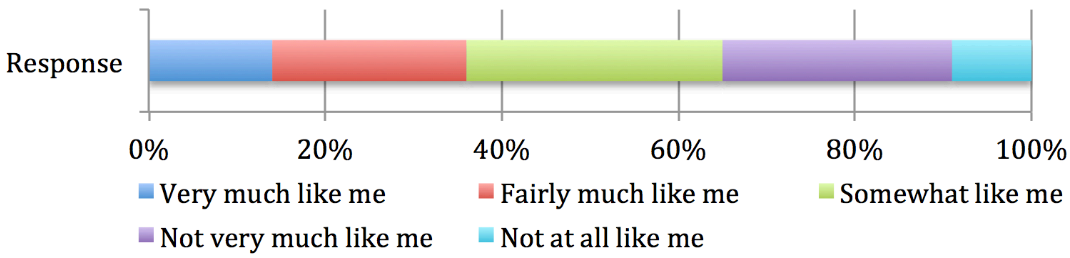


Figure 4.2.51 The distribution of responses to HIFAS statements 39, (n=450), "I often have trouble making sense of things I have to remember." for all students.

The last statement introduces creativity, as this is a feature of the new specification for junior cycle science, (SJCS). Students were asked to position themselves between, “Not at all like me”, and “Very much like me” for, “I like project work because it allows me to be creative.”, (15). When all responses were analysed it was clear that first year students, (n=112), were more in agreement with this statement, (p=0.005, t=14.782, df=4), than the other four year groups, (n=355), whose response distribution was fairly uniform, (p=0.328, t=3.441, df=3). The strength of the relationship between year group and preference for project work was found to be moderate, (r=0.523). The first year and combined rest of school distributions are shown below and the group statistics are in the table that follows.

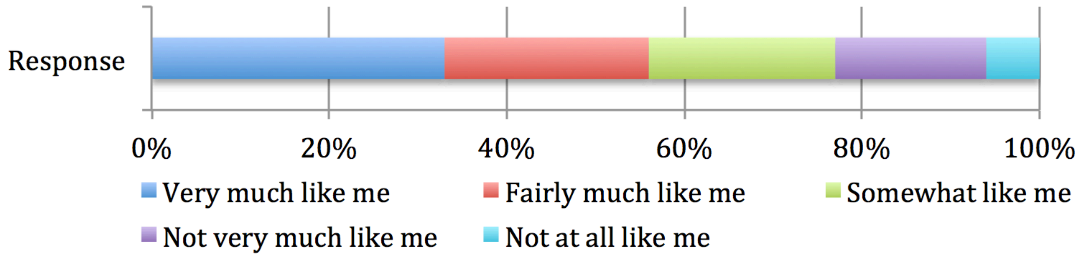


Figure 4.2.52 The distribution of responses to HIFAS statements 15, (n=112), “I like project work because it allows me to be creative.” for first year students.

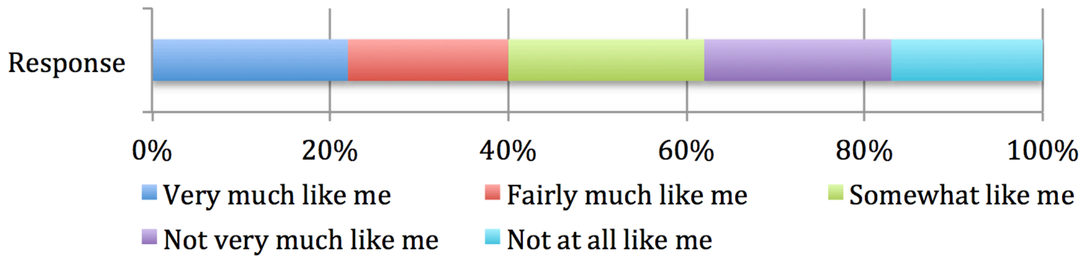


Figure 4.2.53 The distribution of responses to HIFAS statements 15, (n=355), “I like project work because it allows me to be creative.” for second, third, fifth and sixth year students.

Table 4.2.12 Group statistics for the analysis of variance in response to "I like project work because it allows me to be creative.", (n=467)

Year group	Sample size (n)	Mean rank
1	112	270.56
2	83	213.97
3	87	236.67
5	107	231.40
6	78	203.41

Some suggestions for additional statements from third year students were, "I prefer subjects with learning facts more than learning numbers or learning problem solving.", and, "I prefer learning about issues that will affect me in real life.". A fifth year student also picked up on perceived relevance with, "I think a lot of the work/learning we do doesn't relate to real life". Questioning the whole purpose of schooling, and reflecting some of the opinions offered in the literature review, was, "Do you believe school should merely equip students with the skills required to get a job?", from a third year student. A second year offered, "Do you like the new science sylabus or think its useful?", (spelling from original).

Other suggestions for statements that should have been included were, "I'm clever but I am not when it comes to school work", (5th year), "Does the iPad distract you during class?", (3rd year), "Should you be using the book during class", (2nd year), and finally, "Should teachers be allowed to tell jokes?", (1st year).

4.3 Ways of learning questionnaires I and II

In section 2.2.13, of the literature review, the student voice, with regard to perceptions around their science education, was first heard through responses to the Relevance Of Science Education, (ROSE) survey, (Matthews, 2007), and then by the data presented from the Student Review of the Science Curriculum, (SRSC), (Murray & Reiss, 2005). While ROSE restricted itself solely to curriculum content, the SRSC also addressed pedagogy.

As part of the research that forms the basis of this thesis, the author utilised the pedagogically oriented SRSC questions, with minor alterations to the wording of some statements to open up the questionnaire for a wider selection of subjects, in the 'ways of learning questionnaire I', (WLQ1), (Appendix IX). This was undertaken in an attempt to establish, first, whether student perceptions of effective teaching and learning strategies in an Irish context in 2018 to 2019 were in alignment with those from the English General Certificate of Secondary Education, (GCSE), in 2001 to 2002. Second to this, students were asked to gauge the frequency of each strategy identified in the SRSC in terms of those they experienced 'most often' and 'least often' on the 'ways of learning questionnaire II', (WLQ2), (Appendix X), to establish whether their pedagogical experience aligned with the students' perceived needs, in line with the first research question.

Student reported data on the ratio of teacher-talk to student-talk and to silent study, in all lessons, was also collected using the WLQ2, as were attitudes to group work.

Most informatively, the student view of the structure of an ideal lesson for learning was also revealed.

4.3.1 Effective and enjoyable learning

When the results from the 'ways of learning questionnaire I', (WLQ1), were compared with data collected as part of the Student Review of the Science Curriculum, (SRSC), (Murray & Reiss, 2005), a direct correlation was observed as the two tables that follow demonstrate, (Tables 4.3.1 and 4.3.2).

Table 4.3.1 Responses to questions on how effective and enjoyable students found different ways of learning (n= 1450), redrawn from the original in The student review of the science curriculum by Murray & Reiss, 2005, p.4

Ways of learning	Useful and effective (%)	Enjoyable (%)
Taking notes from the teacher	45	15
Looking at videos	27	75
Reading the textbook	17	18
Taking my own notes from books etc.	24	13
Copying notes from the board	23	17
Doing a science investigation	32	50
Making a science presentation in class	17	43
Researching science on the Internet	8	44
Going on a science trip or excursion	30	85
Doing a science experiment in class	38	71
Having a discussion/debate in class	48	64

In both studies students regarded taking notes from the teacher, doing experiments and having discussions or debates in class to be the most effective learning strategies, while going on trips, looking at videos and conducting experiments were considered to be the most enjoyable. The Irish findings also almost exactly mirror those from the original survey with regard to the students' views on the least useful and least effective pedagogies in that reading the textbook, using the internet and making presentations to the class were least valued and most unpopular.

Table 4.3.2 Responses to questions on how effective and enjoyable students found different ways of learning (n=394), from the 'ways of learning questionnaire I', (WLQ1)

Ways of learning	Useful and effective (%)	Enjoyable (%)
Taking notes from the teacher	55	12
Looking at videos	24	58
Reading the textbook	11	2
Taking my own notes from books etc.	34	6
Copying notes from the board	21	8
Doing research or a science investigation	18	17
Making a presentation to the class	10	5
Using the Internet	14	18
Going on a trip	29	80
Doing an experiment in class	47	57
Having a discussion/debate in class	37	37

When these results were compared with the reported everyday classroom practice however, a wide chasm between what students value and what they experience was noted, as is shown in Table 4.3.3. Students reported that the most frequently employed teaching strategies were the chalk-and-talk of listening to the teacher and copying notes from the board, in addition to reading the textbook. Using the Internet as a tool for learning also appeared as a frequent classroom activity in comparison to the other options available. The classroom discussions and experiments, that were prominent as teaching and learning strategies regarded by students as most effective, were infrequently encountered while, at the same time, approaches that they regarded as least effective, namely reading the textbook or using the internet, as has already been identified, were reported as relatively common classroom practices.

Table 4.3.3 Responses to questions about the most and least frequently employed classroom teaching and learning strategies experienced by students, (n=142), from the 'ways of learning questionnaire II', (WLQ2).

Ways of learning	Most often (%)	Least often (%)
Taking notes from the teacher	64	3
Looking at videos	2	41
Reading the textbook	68	11
Taking my own notes from books etc.	16	20
Copying notes from the board	72	4
Doing a science investigation	15	13
Making a science presentation in class	6	36
Researching science on the Internet	30	11
Going on a science trip or excursion	-	94
Doing a science experiment in class	12	23
Having a discussion/debate in class	15	44

4.3.2 Classroom Practice

The previous section considered a number of classroom activities that students might encounter in school with regard to their engagement with the curriculum but the 'ways of learning questionnaire II', (WLQ2), also probed the frequency with which student-talk was utilised to facilitate learning. Students were asked to consider their experiences in all subjects and to shade the respective percentage of the time they considered they spent conducting three specific activities on an appropriately boxed chart. These activities were, ‘listening to teacher’, ‘working quietly’ and ‘talking and working in a group’, (Appendix X). Further clarification was given to participants such that ‘listening to teacher’ should be considered as an activity where they sit in silence and are talked at, ‘working quietly’ as completing tasks such as workbook exercises without any interaction with their peers, and ‘talking and working in a group’ to be where they are free to discuss and co-construct their learning with their peers or the teacher. The sample, (n=114), included students from all three junior cycle year groups.

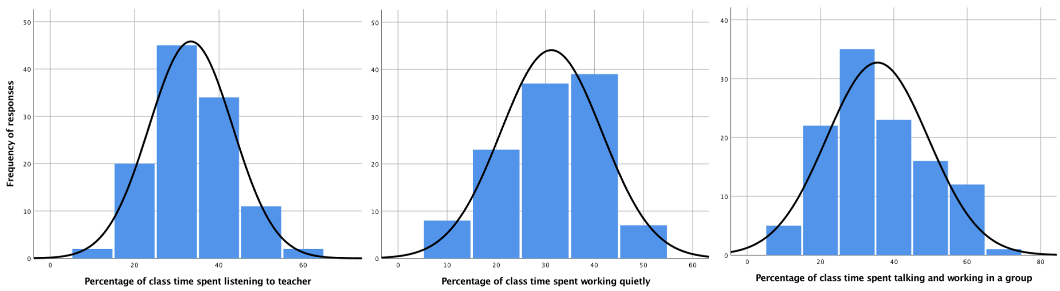


Figure 4.3.1 The distribution of responses, (n=114), to the ways of learning questionnaire II, (WLQ2), request for responses to how much time do you spend ‘listening to teacher’, ‘working quietly’ and ‘talking and working in a group’ for junior cycle students.

The means for each option indicate that students reported spending approximately equivalent time on the three activities identified. In essence then, for roughly two thirds of their time in school, a minimum of four hours per day, students were silently engaged with their work, either through instruction or practice.

4.3.3 Groupwork

As part of the 'ways of learning questionnaire II', (WLQ2), students, (n=120), from all years of junior cycle were asked to consider whether they liked to talk through work with a group in class. The question has the intended purpose of assessing students' position with regard to Vygotsky's suggestion that language is a social tool that can be used to develop understanding; or in his words, that 'Thought is not expressed but completed in the word.', (Vygotsky, 1987, p251). The results obtained were comparable with those from the 'how I feel about school', (HIFAS), survey, (section 4.2.5), in that 81% of students who responded stated that they preferred group work activities. Therefore the results indicate that in an average class of twenty-four students, five individuals preferred not to engage in activities of this type.

When asked to explain their positions, and to identify the best and worst aspects of group work, an interesting set of responses was given as the following describes.

Student reasons for preferring group work predominantly focussed on the potential educational value that they identified discussion with their peers could provide. One response that illustrates this is, "Talking through my work, it helps me to understand it better". Others mentioned the freshness that a different person might bring to classwork with comments such as, "I like to hear what other people said about the topic”, and “because we can show each other new ideas and help each other if we get stuck or confused”. The two heads being better than one approach to problem solving was a very common theme, articulated further in comments such as, “sometimes the teacher is busy and a friend can explain something to me that I don’t understand” and “because we can help each other if we get stuck or confused”. Using one’s peers to help produce the best work possible appeared in, “Because I like to get everyone’s answer so I can develop or better mine” and “I feel like it makes me more confident and benefits my work as I get constructive critiscm”. Building confidence through working with others was also a very common theme. Finally, enjoyment was mentioned in comments such as, “I like talking because it makes work less boring” and perceived value in “Because I feel like its more educational than just writing down notes”, (spelling from original).

The aspects of group work that students identified as best and worst were common to the sample as a whole, whether or not the individual responding wished to engage with activities of this type.

Students included “it is the interaction & Being able to share a laugh yet complete the work”, and “you dont have to just sit down and be quiet the whole time” as positive aspects as well as the impression that “it betters your communication and co-operation skills”. Day’s construction zone, (section 2.2.11), similar to Vygotsky’s zone of proximal development, was mentioned a number of times in comments like “because someone might be better at something making your work easier and you can learn to be as good as them” and “being able to share your views while learning from others around you”, (spelling from original).

Negative aspects noted were “having a group that doesn’t do anything”, “Not being able to concentrate”, “People distracting you from your work” and “A lot of noise”. That “some people don’t respect your answer” and “people may get left out & unhappy” were also mentioned. Two longer responses were:

> the worst thing from groupwork is that someone is always slacking off/messing and that always frustrates me since I try my hardest, so why shouldn’t they? So that steers me away from groupwork

and

> The worst thing is that if we’re doing a project in a group we have to rely on others because we’re all getting the same grade.

4.3.4 Student-reported ideal lesson structures

As part of the ‘ways of learning questionnaire II’, (WLQ2), students were asked to outline their concept of an ideal student-centred, learning-focussed lesson. The most common structures are described below in decreasing order of popularity.

Just under one third, (32%), of comments featured “Taking notes from the board” as a prominent component of an ideal lesson routine; essentially a delivery model of instruction, where the notes produced by the teacher are consumed by the students. This appeared in replies such as, “teacher explaining lesson and giving us notes to take down for later study” and, “taking down more notes as it would help us in an exam environment”, (spelling from original). Slightly less passive were responses that included some active participation by the students as in, “an ideal learning lesson for me would be a class of just taking notes and discussing them” or, “copying down notes, then answering questions”. The amount of time spent on these activities was typically identified along the lines of:

> I’d like to listen to the teacher for a quarter or a third of the class. Take down notes for the second third and then practice work or do practical work for the last 3rd

Only one individual suggested that the notes could be self generated:

> An ideal learning lesson routine for me would be to listen carefully and make your notes to help you and that can help you a lot in work or projects

Slightly fewer respondents, (30%), included, “talking and debating, group work”, as important activities that could promote learning in an ideal lesson. One student, articulating the thoughts of many, suggested that, “If we got put into groups with different people my brains knowledge would grow”, and another proposed the best lesson as one that would involve, “Discussing the topics as a relaxed class group with the teacher”. The most explicit response was:

> 1) reading talking about the topic 2) groupwork on the topic 3) class discussion. To come in and not just do silent work but to be actually challenged where you have to think and not just copy what the teacher saying. In my opinion it's also easier to work in an environment with some noise and discussion. Also being allowed to choose where you sit.

Ten percent of responses included references to, "watching videos and talking". Two students indicated how these could be incorporated when they wrote, "The best thing I think is watching viedoes and go outside and do something related to it", and, "Reading the book answer the question whatch a few videos to fix my mistakes", (spelling from original).

An allocation of time to different activities was given by one individual, who formed part of the six percent that mentioned quizzes and games, in:

> I would like 10 mins of learning, 10 mins of working, 5 mins of correction/Reflection and 15 mins of fun stuff like quizzes or practical work. I would like the above routine to be enforced in our school as it would make classes more enjoyable

Only four percent of students referred to, "Going on trips to a landmark were doing topic on for educational purposes of course", the same proportion in fact as who suggested, "An experiment would be an ideal learning lesson as we can see what happens for ourselves".

Responses from students who expressed their aversion to group work included, "doing work from the workbook", "I would like to do more work instead of talking", and,

> learn more from the text book and less experiments. Keep quiet an no one will distract me while I am attempting to focus, (spelling from original).

The exception to teachers expanding on topics, mentioned in the literature review, appeared in the text of a student who expressed a wish, “For teachers to get to the point and not talk alot”. The most extreme response of all was:

> more work than fun and expirments. Testing. Doing more work. Tests every Friday work, study, no fun. (spelling from original)

4.4 The impact of student action cycles on attitudes towards science

Attitudes towards science, and any impact that student action cycles might have on these, were assessed by analysis of responses to statements from the 2015 and 2019 Trends in International Mathematics and Science Study student questionnaires, (TIMSS), (https://timssandpirls.bc.edu), in addition to exit ticket data.

4.4.1 Analysis of TIMSS student engagement and attitudes responses

TIMSS is an international study of mathematics and science achievement at both primary and secondary level that takes place every four years and was first implemented in 1995. In addition to the analysis of student achievement, attitudes to learning, features of the home environment, school climate and a range of other factors are investigated through student, teacher and parent questionnaires.

The TIMSS statements relating to attitudes towards science were used in this study to allow for comparison with international data although unfortunately the results from the 2019 series are not expected to be published until December 2020. In addition, direct comparison with the 2015 data set is confounded by the fact that in the final report, responses to multiple statements were combined and the four-point Likert-scale, offered to the students, was conflated down to three categories. The results, however, provide a snapshot into how Irish second year students' views compared with the international average of other countries that took part in the 2015 study.

In the section of the 2015 TIMSS report addressing "Student Engagement and Attitudes", percentage responses to whether students like learning science, feel confident in the subject, or hold it in value are presented. These are displayed, as benchmarking, at the beginning of each relevant subsections.

4.4.2 Do students enjoy science?

The degree to which students enjoy learning science was addressed by Trends in International Mathematics and Science Study (TIMSS) 2015 question 21 and TIMSS 2019 question 19. A graphical representation of the 2015 results from twenty-nine countries, including Ireland, is shown below for comparison, as is the data from the complete year groups from which the study groups were taken. The pre- and post-intervention data for the 2015 and 2018 study groups using student action cycles (SACs) are also presented.

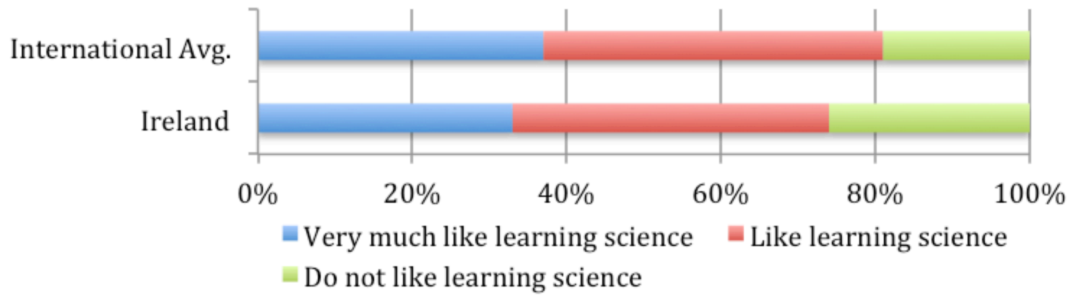


Figure 4.4.1 The International average and Irish distribution of responses from the 2015 TIMSS statement concerning whether students liked learning science drawn from data retrieved from https://timssandpirls.bc.edu

All second year students, (n=148), following the junior certificate science syllabus, (JCSS), were assessed at the end of March in 2015 and the responses to the statement "I enjoy learning science" separated by gender (Figure 4.4.2) can be seen to approximate the Irish mean for girls (70%) and boys, (72%), (TIMSS=74%).

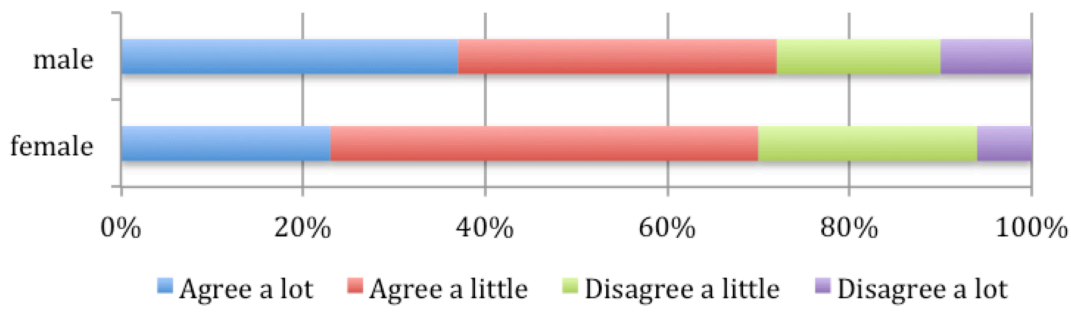


Figure 4.4.2 The responses to the 2015 TIMSS statement 21a "I enjoy learning science" separated by gender for second year students, (n=148).

The 2015 sample group were, in general, less enthusiastic about science on the pre-test than other colleagues in their year, as can be seen in Figure 4.4.3, with only sixty-eight percent of girls and fifty-five percent of boys in agreement that they enjoyed learning it.

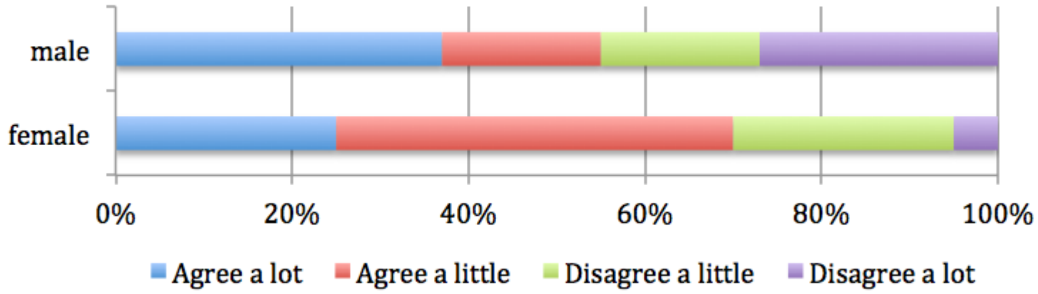


Figure 4.4.3 The responses to the 2015 TIMSS statement 21a "I enjoy learning science" separated by gender for second year students, (n=51) before implementation of student action cycles (SACs)

When this was repeated in 2018, at the beginning of second year for students, (n=158), engaging with the specification for junior cycle science, (SJCS), using the trial questionnaire for the 2019 study, the attitudes towards the subject were much more positive with eighty-nine percent of girls and seventy-two percent of boys reporting favourably on their feelings towards the subject, (Figure 4.4.4).

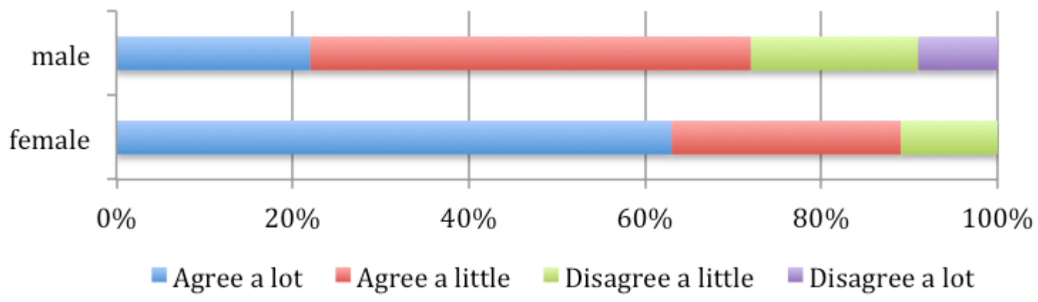


Figure 4.4.4 The responses to the 2019 TIMSS statement 19a "I enjoy learning science" separated by gender for second year students, (n=158).

A sample of the 2015 cohort, (n=51), whose learning involved the use SACs was re-assessed post intervention and the results are displayed in Figure 4.4.5.

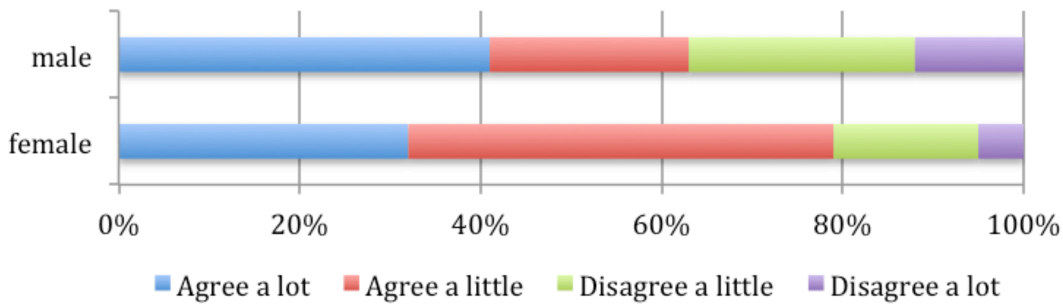


Figure 4.4.5 The responses to the 2015 TIMSS statement 21a "I enjoy learning science" separated by gender for second year students, (n=51) after implementation of student action cycles (SACs)

As illustrated above, (Figure 4.4.5), students rated their enjoyment of the subject higher after using SACs than beforehand, (p=0.002, Wilcoxon Test, Z=3.162). While 62% of students in total stated that they agreed "a lot" or "a little" pre-implementation, this rose to 71% afterwards although this change in attitude was found to be relatively weak, (r=0.443).

When the same analysis was performed on the 2018 cohort pre- and post-implementation of SACs the following was revealed, (Figures 4.4.6 and 4.4.7).

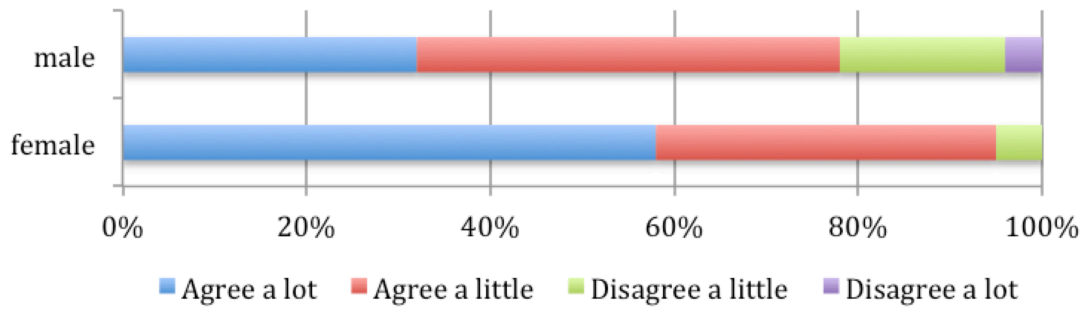


Figure 4.4.6 The responses to the 2019 TIMSS statement 19a "I enjoy learning science" separated by gender for second year students, (n=47) prior to implementation of student action cycles (SACs)

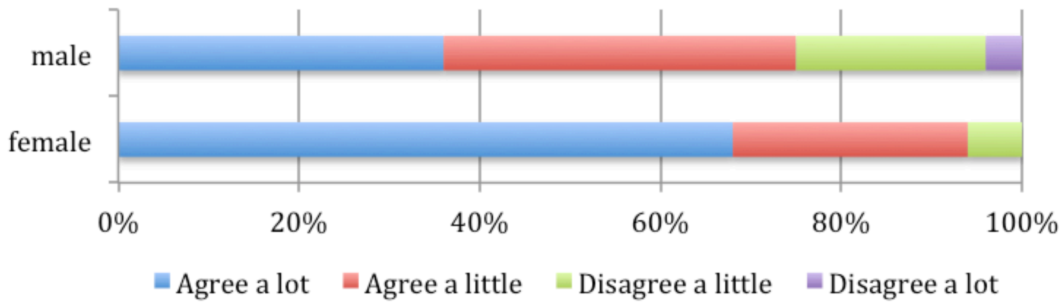


Figure 4.4.7 The responses to the 2019 TIMSS statement 19a "I enjoy learning science" separated by gender for second year students, (n=47) after implementation of student action cycles (SACs)

Although there are minor differences in the percentage of students identifying with the various attitude categories, no evidence can be found that these changes arose from the use of SACs, (p=0.317).

Further analysis of responses to TIMSS may be found in Appendix XI.

4.4.3 Motivation to engage

Whether student action cycles impact on attitudes towards science was also examined by the use of a number of different exit tickets.

The first of these, which could better be described as an 'entry ticket', was a short five item five-point Likert-scale questionnaire, (Appendix IV), presented to students after topics, or learning outcomes, were introduced but before they had begun to engage with these. The questionnaire was given to two second-year junior cycle classes six times over a two-year period; thrice prior to student action cycles (SACs) and thrice before standard units of work. This was done in an attempt to overcome possible curriculum bias, and the total responses for each strategy were collated separately.

The first four items on the ticket asked students to rank their position from one to five on the options of "Motivated/Unmotivated", "Interested/Uninterested", "Involved/ Uninvolved" and "Excited/Bored"; one indicating strong affinity with the first word in each of the pairings. The last option was reverse scored and asked students to position themselves between "Dreading it" and "Looking forward to it". Scores were then tallied and the results are shown in Figure 4.4.8 on the next page.

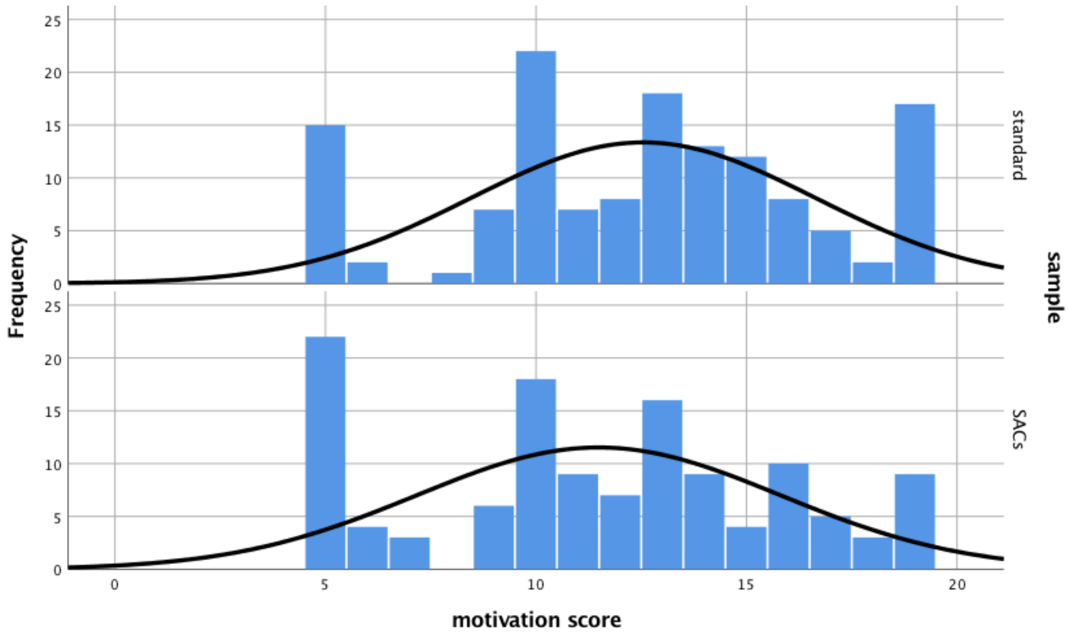


Figure 4.4.8 The responses to a five statement Likert questionnaire examining the extent of student motivation towards their learning prior to engaging with tasks for standard instruction, (n=137) and for student action cycles, (SACs), (n=126)

Application of the one-sample Kolmogorov-Smirnov Test confirmed the graphical representation of an absence of a normal distribution, ($p< 0.01$, $t= 0.093$). Differences were found between the motivational scores for students undertaking standard instruction and SACs, ($p=0.047$, Mann-Whitney $U=7416.5$, $Z=1.982$).

Taking a score of fifteen as a neutral response, where students neither express overall motivation or demotivation, it can be seen that the number of individuals scoring less than fifteen, (motivated), rose from 68%, with standard instruction, to 75% with the prospect of engaging with SACs, although the strength of this relationship was found to be relatively weak, ($r=0.122$).

Table 4.4.1 Group statistics for the analysis of the effect of the prospect of student action cycles, (SACs), or standard instruction on student motivation.

Sample	sample size (n)	mean rank	Sum of ranks
standard	137	140.86	19298.50
SACs	126	122.36	15417.50

4.4.4 Reflections on learning

Over a two year period, at the end of the Autumn and Spring terms, second year students were asked to briefly respond to a set of five questions, as a reflection on their learning. The questions given were: "What did you enjoy the most?", "What was easy?", "What was hard?", "What helped you learn most?" and "What did you do when you found something hard or difficult to understand?". The questions were designed to be very open-ended to collect as wide a selection of responses as possible in an attempt to answer the research question, 'How closely do specific pedagogical approaches align with students' perceived educational needs and attitudes towards science?'

In answer to the first question, "What did you enjoy most?", an overwhelming majority of responses referred to work that students had planned and completed themselves as part of the student action cycles, (SACs), "Greener Greens?", "Sustainable Living" and "Closer-Colder". In reference to "Greener Greens?", where students explored issues around sustainable food production, their carbon footprint and biodiversity, (http://www.confeyscience.com/greener_greens.html), one student wrote, "The most interesting thing was the diversity of the food market. I enjoyed researching everything about the food market". Another summed up her feelings with, "The food project was the most interesting cos we could plan it ourselves and it was fun". The openness of the learning approach encouraged one student to explore the issues outside of school where he expressed that, "What I found most interesting was asking my grandad about what food he ate when he was growing up". Two other responses that are of remark are:

> I enjoy learning about nutrition and food science so I enjoyed doing something a bit different; looking at where food is grown and how it gets here other than what is in food and how it affects our health.

and

> I tought the most interesting thing we have done was when we hatched chicks, I tought it was very interesting because I got to learn that they survive without their mother. I enjoyed watching the chicks evolve from them being in an egg, to being without feathers and then being with feathers, (spelling from original)

The "Sustainable Living" SAC asked students to find suitable ways of presenting their findings around energy generation and conservation to their peers. Many latched on to the idea of creating a board game and this led to comments such as, "I enjoyed the Energy board game the most because it was the most fun thing we did all year" and, "The board game was the most exciting thing I loved making up the rules and researching the energy calculating the numbers was fun".

On a more general note were comments such as, “What I found interesting was all the research we found out”, “I enjoyed working together and doing a really good job because it made me feel very proud” and “I enjoyed the teamwork”.

Responses to “What was easy?” and “What was hard?” generally listed curriculum components but when they referred to learning strategies typical responses were:

> I found learning by doing group work the easiest method. If I got stuck I asked people around me and if they didn’t know I’d ask [the teacher] or [the teacher] first about whatever I didn’t understand.

or, “What I found most difficult was doing the project as I wasn’t sure what to write about.” and “The hardest part was trying to get our teamates to be quiet and help.”

Only one student responded negatively, and this was about his whole experience in science, stating that:

> I didn’t really find anything difficult but it would’ve nice to have notes and use our science book that we havn’t used and I would really like to use the book in class because it helps me learn. Essays always help me learn and reading from a book but we never have to do that. I haven’t really learn’t alot because we have no way of studying without using the book but if we used the book I could be learning better, (spelling from original).

When asked, “What helped you learn most?”, the majority of replies referred indirectly to the student action cycles, where students were free to choose who they worked with. Typical responses were, “The thing that helped me learn was a fun class because we were working together to find out.” and “Working in big groups helped Me learn.” On a more general note were comments such as, “I’d say a positive enviorment helped me learn.”, (spelling from original). One very insightful student remarked:

> What helped me learn most was by learning from my mistakes and fixing it myself. If I found something really hard I asked my classmates or the teacher.

The final question, which asked, “What did you do when you found something hard or difficult to understand?”, again made no reference to the learning strategy but once again the overwhelming responses referred to the group work of SACs as in, “I asked my partners to help me understand”, or, “If I got stuck I would either ask my team for help or go online and research the subject for help.” and “When I found something difficult or hard I asked my friends in my group what to do.”

4.5 The mindset orientation of students in this study

In an attempt to probe the cause of a perennial observation of a decline in students’ reported confidence in science, the mindset of students was assessed by the application of Diehl’s Mindset Quiz, (DMQ), (Diehl, 2008), (Appendix VI), and the

Dweck Mindset Instrument (DMI), (Dweck, 2000), (Appendix V). Mindset is identified as a continuum from fixed, (where inherent, genetically predetermined ability limits performance), to growth, (where performance can be improved through the application of will). It was anticipated that a move from growth to fixed mindset might appear concomitantly with the increasing demands of curricula, thus explaining the reported decreases in confidence.

4.5.1 Results from Diehl's Mindset Quiz (DMQ)

Diehl's Mindset Quiz, (DMQ), a 20 item, 4-point Likert-scale questionnaire, founded on Dweck's theory, was used to assess individuals on a continuum from fixed to growth mindset based on responses to statements about personality and ability. Participants are asked to select between, "Strongly Agree", "Agree", "Disagree" and "Strongly Disagree". Statements, 1, 4, 7, 8, 11, 12, 14, 16, 17 and 20 are scored such that "Strongly Agree" is awarded zero points and "Strongly Disagree" gains three points. The scoring is reversed for the remaining statements. The assessment yields a maximum score of 60 points; regarded as indicative of a strong growth mindset. The point range for student responses, and the corresponding mindset categorisations, are identified in Table 4.5.1.

Table 4.5.1 Coding system for Diehl's Mindset Quiz to identify students' perceptions of their mindset orientation redrawn from the original in Diehl, 2008

mindset orientation	point range
Strong growth mindset	45-60
Growth mindset with some fixed ideas	34-44
Fixed mindset with some growth ideas	21-33
Strong fixed mindset	0-20

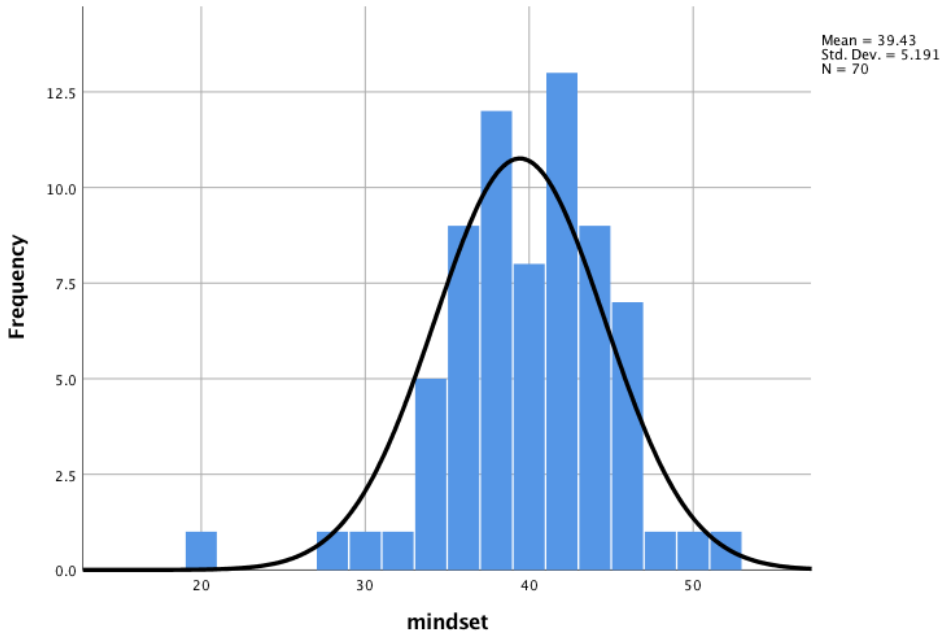


Figure 4.5.1 The distribution of First-year student scores (n=70) on Diehl's Mindset Quiz drawn from 2016 data.

The initial cohort chosen for assessment was of first-year students engaging with the specification for junior cycle science (SJCS) for the first time; after its introduction in 2016. The first-year students' scores on Diehl's Mindset Quiz were found to be approximately normally distributed by application of the one-sample Kolmogorov-Smirnov Test (p= 0.200, t= 0.090).

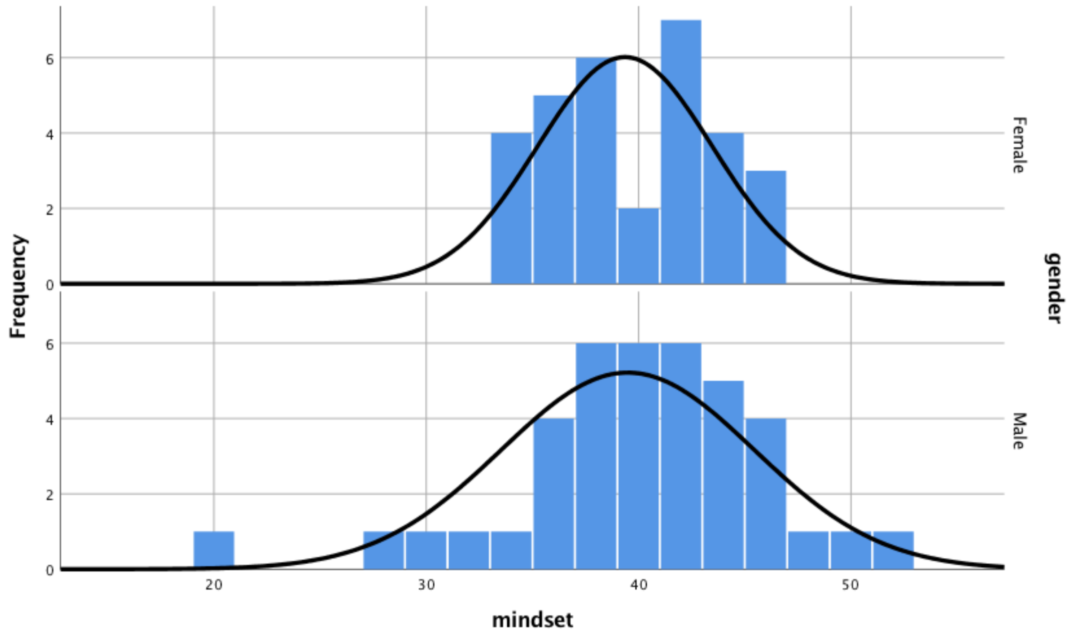


Figure 4.5.2 The distribution of First-year student scores (n=70) on Diehl's Mindset Quiz separated for gender drawn from 2016 data.

Further analysis was conducted to determine whether there was an apparent gender difference in mindset orientation, (Figure 4.5.2). An Independent samples t-test was performed on the data and no evidence of a difference was found between the genders in relation to mindset orientation (p=0.917, t=0.105, df= 68).

The analysis using this instrument, (DMQ), was then extended to include students from all year groups and the results are displayed on the following page.

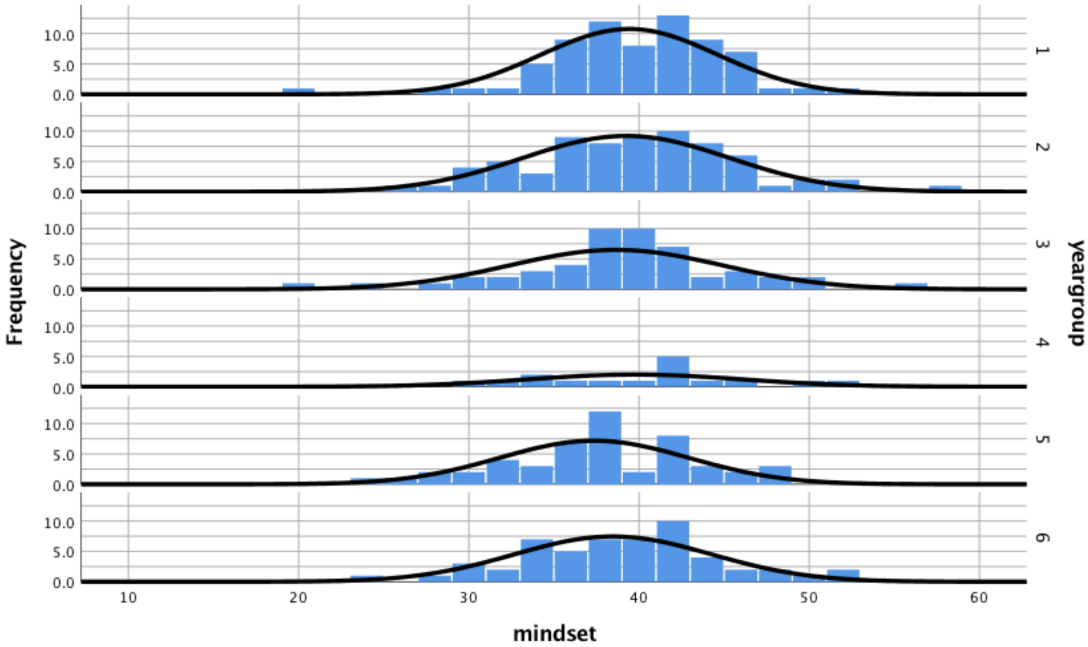


Figure 4.5.3 The distribution of all student scores (n=311) on Diehl's Mindset Quiz, (DMQ), for all students drawn from 2016 data.

A one-way ANOVA was employed to determine whether there was a difference in terms of mindset orientation between the year groups. No evidence of such was found ($p=0.423$, $F=0.991$, $df=5, 305$).

4.5.2 Dweck's Mindset Instrument (DMI) responses

The Dweck Mindset Instrument (DMI), is comprised of two sets of eight statements relating to an individuals' self-perceptions of intelligence and talent. Each set examines how students identify with the trait through their responses on a six-point Likert-scale where they have the options to 'strongly agree', 'agree', 'mostly agree', 'mostly disagree' or 'strongly disagree'. Strongly agreeing to any of statements 1, 2, 4, 6, 9, 10, 12 and 14, which are regarded as characteristic of a fixed mindset, yields a score of one, while doing so to any of the remaining statements is rewarded with a reversed score of six. Scores for each statement are then tallied and averaged to produce an overall mindset score. Values between 1 and 3 are regarded as indicative of a fixed mindset, those who score between 3.1 and 3.9 are regarded as undecided, and any score between 4 and 6 represent a self-perception of growth mindset. Students from across the junior cycle cohort were assessed and the results are displayed in the following graph.

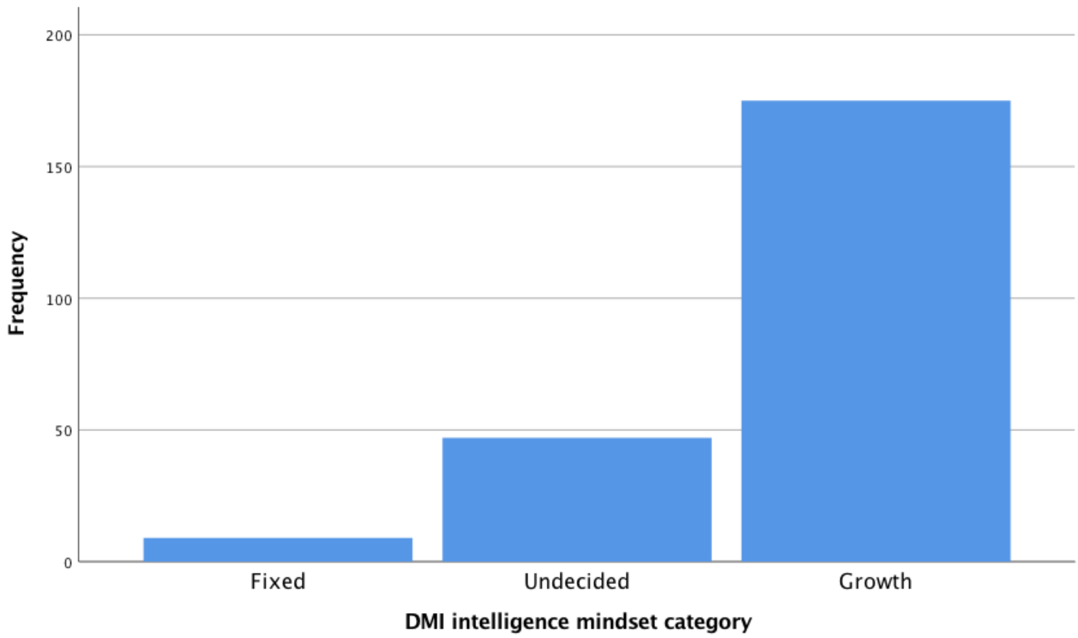


Figure 4.5.4 The distribution of students, (n=231), within each mindset category as identified through the application of the Dweck Mindset Instrument, (DMI), with regard to perceptions of intelligence, for all students drawn from 2018 data.

As can clearly be seen from Figure 4.5.4, and in confirmation of the results from Diehl's Mindset Quiz, (DMQ), the vast majority of students identify with a growth mindset; perceiving intelligence to be a malleable trait.

4.5.3 Responses to the 'Intelligence?' survey

In the surveys described in the previous sections, there is an underlying assumption that the students' perception of intelligence is a definable commodity that matches that of the researcher(s). To probe how universal a concept of intelligence might be, students, (n=354), were asked to answer six short questions on the topic. All spelling and grammar in the quotes is as written by the students.

When asked, "What does the word intelligence mean to you?" responses varied from single word answers to extended prose and identified a variety of themes. For example, the following was received from a first year student.

> Intelligence means, in my opinion, having common sense and being informed about topics. The main intelligence is to be smart in how you act, what you do & when you do things. Intelligence isn't something you can define.

Another responded, "It means wisdom and imagination rather than konlledge,[knowledge]." More diverse were replies such as "how well a person can comprehend and understand a question", "How you handle different challenges that may come up in life.", "Academically high and ability to solve complex problems" and

"Intelligence means someone who knows everything and doesn't need to try hard." Another student voiced the view of a number of individuals when he wrote, "It is the cop on to know you have to work hard to learn stuff".

Students clearly identified intelligence into categories such as memory in statements like, "I think it means the kinda like storage in your brain which holds knowledge of everything you learn.", and perception in, "Intelligence is how you see the world. You might be intellectual but are oblivious to obvious things."

Morality appeared in, "To understand what is right and wrong and to be smart about it" and also,

> i dont think intelligence means 'how smart you are' but about how you think about yourself and others and how aware you are.

The most common form of answer, appearing in 58% of responses, included the words "being smart", followed with 37% that included the words "knowing", "knowledge" or "information". "Wise" and "wisdom" were present in 15% and "clever" and "brainpower" combined in 8% of the answers. "Street smart", "common sense", athletic/sports and musical ability and "being able to think outside the box" also appeared frequently.

The second question posed to the students was, "Do you think there are different types of intelligence? - If you said yes, what might they be?". Nine percent of students, (n=32), answered “no” and of the remainder by far the largest number of responses identified differences in subject areas, both academic and social. Whereas some students listed suggestions such as, “emotional intelligence: intellectual intelligence”, or “Yes/smart in class/smart in life”, others went on to be far more descriptive as in the next examples: “Yes, some people can be intelligent in different ways; book smart, fact smart, talent smart, logic smart ect.” or “Yes! You could be intelligent in computers, engineering, carpenting, accounting”.

Wider skills appeared in this student’s understanding:

> Yes you could have football intelligence, basketball intelligence, normal intelligence, be intelligent through maths and science while some people such as explorers are smart through nature and survival skills and so on.

One girl attempted to explain how differences might arise when she said:

> Yes, because their are 2 sides of your brain so of course you do. You might have more intelligence on your left side. Or on your right side you might be able to obtain more information on scientific research.

Even when attempting to disregard the question, students’ responses affirmed a conception that there were different types of intelligence, as in:

> N/A – because intelligence is so broad there are so much things and so much we can learn everyones at different standards of intelligence

In an attempt to delve further into what it is that students regard as intelligence they were asked to name "… the most intelligent person you can think of" and explain their choice. Responses, (n=354), fell into five categories, namely famous people, (52%), friends, (17%), relatives, (14%), undecided, (10%) or their teachers, (7%).

Perhaps unsurprisingly, considering his omnipresent legacy, Albert Einstein topped the list of famous people, followed very closely by Stephen Hawking and then by Leonardo da Vinci, Elon Musk, Nikola Tesla and finally, Roy Keane.

A couple of explanations for their selections were that: "I think Da vinci is intelligent because he had a 21st centry inventer's brain in a body much older." and "I think Einstein is intelligent because people called him crazy but made of the most important discoveries." Stephen Hawking:

> ...was a very good and smart scientist and he was the best scientist to ever exist and you have to be smart to be a scientist.

Roy Keane was regarded as intelligent because:

> the way he was able to pick out passes and read a game of football was just amazing. He also intelligent in looking after his body so he would have minimal pain in later life

Students who chose their friends as the most intelligent person they could think of referred to their abilities to "… answer any question I have…", "… get good academic scores." and how to "handle" themselves in life.

Mothers ranked highest, (50%), for students who chose a relative as the most intelligent person they could think of, followed by their fathers, (36%). Reasons given for selecting them added further dimensions to the understanding of students' conceptions of intelligence. One student wrote that her parents were intelligent because, "They are able to provide for me and my siblings both financially but emotionally". Another, describing her mother, stated, "She managed her life well and created a good life for herself and others". While a third, referring to his father, commented, "He always is so calm and so intellectual and knows what to do in every situation".

Students in the undecided category can be best summed up by this response, which was reiterated by the majority of the group:

> Everybody is different types of intelligent there is not one person who's most important everybody around me is intelligent in their own way.

Those who chose teachers went on to say their reason was that "They know a lot of things".

The fifth question in the 'Intelligence?' survey asked "What do you think affects how intelligent someone is?" The most popular response to this related to genetics, (21%), followed by nurture, (19%). Study, (18%), determination, (16%), and the people around them, (16%), also appeared prominently while their school education, (10%), and teachers, (8%), also were mentioned.

The nature versus nurture dichotomy is interesting in respect of its relevance to statements in both Diehl's Mindset Quiz, (DMQ), and Dweck's Mindset Instrument, (DMI), (section 4.5).

Responses such as, "I think that intelligence is based off species and genetics. Some people are naturally gifted from birth and some aren't" lay at one end of the spectrum while, at the other end were statements such as, "I think a person's child hood teaching can affect how intelligent that person is as people learn faster as a child." In the middle, and covering a few bases was, "Their upbringing, their genes, their school, their outlook on life".

Trying hard, working hard and studying were a common theme.

The final question in the 'Intelligence?' survey, (n=354), asked students "Can people change how intelligent they are?" and if so, "… how do you think they could do it?". This question is effectively a summary of statements one to eight of Dweck's Mindset Instrument, (DMI), and statements one, two, three and sixteen of Diehl's Mindset Quiz, (DMQ). Although, as has been illustrated by the students' responses, which widen the parameters of intelligence, all of the statements of both instruments could be considered encompassed.

Eight individuals reported that they felt intelligence was a fixed commodity while the rest were of the opinion that it could be altered.

One third of the responses referred to study, as in “Yes because people can study a lot more which will make them smarter and a lot more intelligent.” While a further twenty percent rephrased this in terms of hard work or determination, as was explained by this student: “Yes! If your not intelligence you can study really hard and get intelligence and be really smart by dedication”. Associated with study were other responses including learning, (11%), reading, (6%), practice, (3%), paying attention in class, (2%), and going to school, (1%).

Several students suggested being motivated to do so as a force for change, in terms of one’s intelligence, as articulated in this comment: “Yes I believe with enough motivation and drive people can do extraordinary things with their lives.” “Working hard and constantly competing with yourself. Also wanting to better yourself.” was the way another person responded.

One strategy proposed was:

> Surrounding themselves with Intelligent People and reading books on lots of areas like literature, arts, history because that develops Your Intelligence in basic areas.

Life experience was felt to be important for the student who penned these words of advice: “Yes, learn from the mistakes you made in life and improve in them”

Finally, the quote below is relevant as it encompasses both ends of statements about intelligence in Dweck’s Mindset Instrument.

Yes. It depends on the person and how they want to change or improve. They can become the version of intelligence they wish. Some people are just lucky and born with it.

4.6 Cooperation and collaboration

The introduction to this thesis started with a quotation from the specification for junior cycle science, (SJCS), that describes science as a collaborative endeavour. This section examines student perceptions surrounding collaboration, and attempts to answer the second research question, "Do student action cycles impact on student collaboration?"

First, it is important to clarify the distinction between cooperation and collaboration. Cooperation is taken as the act of working together to complete a goal. Collaboration also involves working together, but in addition requires that the individuals have shared responsibility for the task they are working on, make substantive decisions together, and that the work is interdependent; that is, the task cannot be completed without the contributions from all group members.

The rubric designed to measure student collaboration, (Appendix VII), was based around assessment strategies incorporated into SAILS, (strategies for assessment of inquiry learning in science), (section2.4.9) and material produced by the 21st Century

Learning Design partners, (21CLD), (https://www.sri.com/work/projects/21st-century-learning-design-21cld). It was the intention that the rubric be used both formatively and summatively, and to this end it was presented to the students at the start of each activity, to be completed at the end of the planning, the doing and the concluding stages of the task. Four of the statements were scored from 1, for "almost never", to 5, for "always", and summed to derive a score for each student. These statements were, "We discussed how to solve the problem together", "The others listened to my suggestions", "We decided together what we should all do" and "We had a group discussion about our results".

Two *traditional* group work activities and one student action cycle, (SAC), were assessed, with the SAC sandwiched between. When the results were analysed there was no apparent difference in the distribution of responses for the two *traditional* activities, (n=42, n=46), (p=0.866, Mann-Whitney U=946.000, Z=0.169) but the responses from the SAC, (n=45), showed greater collaboration, (p=0.005, Mann-Whitney U=1400.500, Z=2.786), although the relationship was found to be fairly weak (r=0.242).

The distribution of responses for the *traditional* and student action cycle are shown in Figure 4.6.1; where 4 represents the lowest degree of collaboration in that "almost never" was selected for each statement and 20 indicates high levels of collaboration with the "always" option chosen.

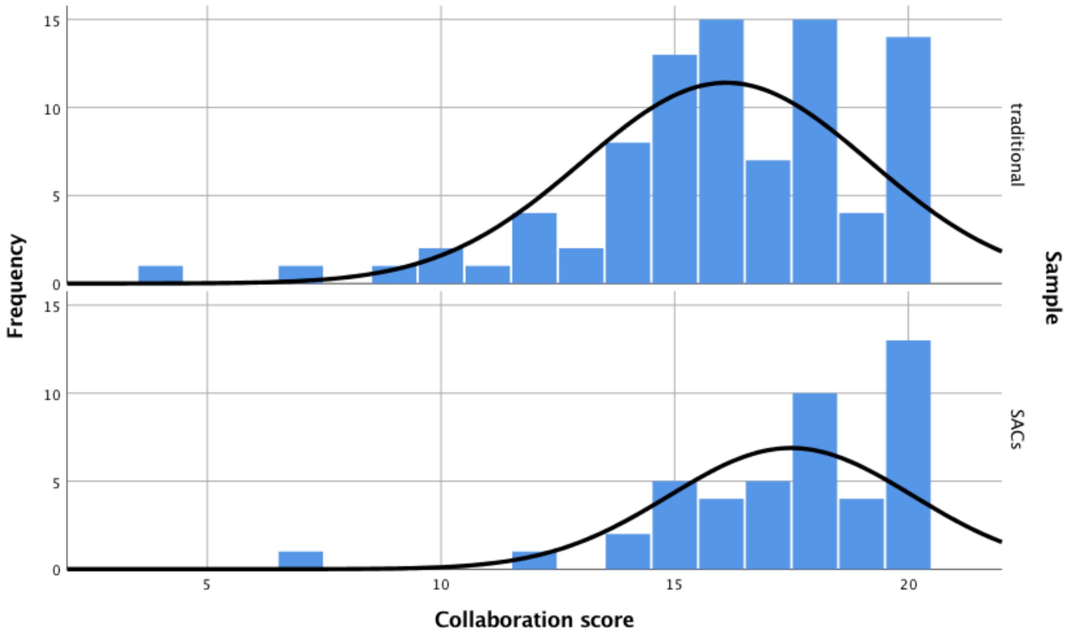


Figure 4.6.1 The distribution of responses for traditional group work, (n=42, n=46 combined), and for a student action cycle, (SAC), (n=45) to statements assessing collaborative behaviour where a score of 4 represents no collaboration and 20, highly collaborative behaviour.

4.7 Cognitive development

The third, and final, research question, 'Do student action cycles impact on cognitive development?' was assessed through the application of two of the science reasoning tasks, (SRTs), developed by Wylam and Shayer, (1978), ("*Volume and heaviness*" and "*The Pendulum*", (Appendix II), comparisons with data from the Drumcondra Reasoning Tests, (DRT), and in later years the CAT4, (Cognitive Ability Test-4), and also with junior certificate examination results. As will be seen in the results that follow, and the later discussion of findings, no great impact was discernable.

4.7.1 The Cognitive level of student intake

Data from first year students on the "*Volume and heaviness*" science reasoning task, (SRT), were compared over a five year period to determine whether there were any appreciable differences between the cohorts. As can be seen from Figure 4.7.1, the 2014 year-group contained a larger proportion of students identifying at the lower levels of cognition, whereas the 2016 distribution was slightly skewed towards the higher levels.

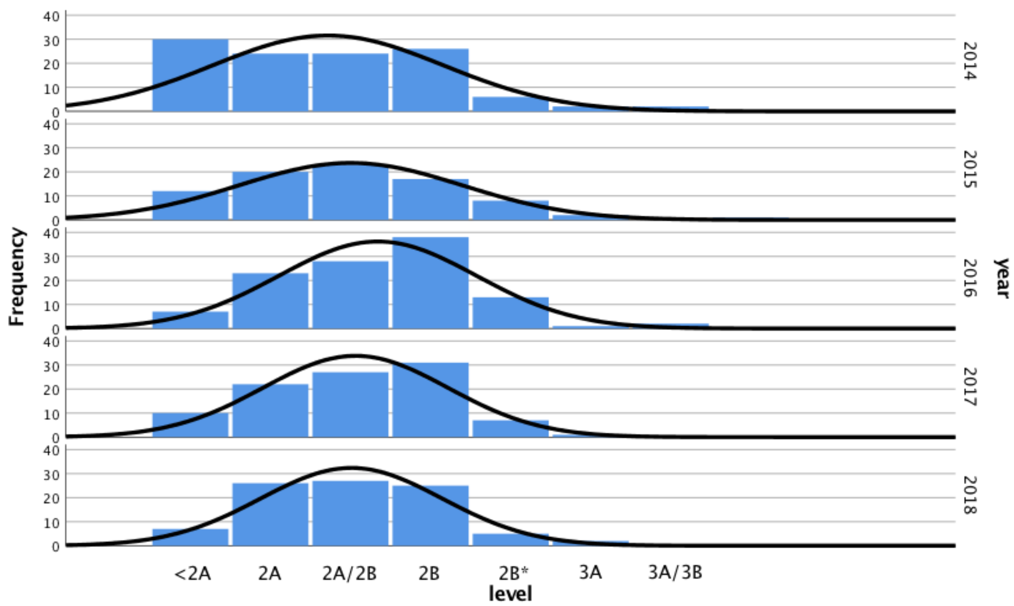


Figure 4.7.1 The distribution of cognitive levels for consecutive years as established through application of the "*Volume and heaviness*" science reasoning task, (n=499)

The appearance of alterations in the distribution of cognitive levels with different intake years was analysed, (p=0.006, Kruskal-Wallis H= 14.538, df= 4), with the group statistics displayed in the table that follows.

Table 4.7.1 Group statistics for the analysis of variance in cognitive level as assessed through application of the "*Volume and heaviness*" science reasoning task with different intake years, (n=499)

Year group	Sample size (n)	Mean rank
2014	114	215.04
2015	83	243.36
2016	112	285.10
2017	98	257.28
2018	92	248.82

When a comparison between the cognitive level determined for each student by the "*Volume and heaviness*" task was made with their corresponding percentile rank data for verbal reasoning and numerical ability on the Drumcondra Reasoning Test, (DRT), or in later years, with their verbal, quantitative, non-verbal and spatial percentiles from the CAT4, (Cognitive Ability Test-4) the following was noted.

A fairly weak but positive correlation, (Appendix XII), was observed between the Piagetian sub-stage and the verbal reasoning percentiles, (r_p=0.390, p<0.001) whereas a moderate, but also positive, correlation was observed with the quantitative reasoning percentiles, (r_p=0.439, p<0.001). A moderate and positive correlation was also observed between the Piagetian sub-stage and the nonverbal reasoning percentiles, (r_p=0.438, p<0.001) and with the spatial reasoning percentiles, (r_p=0.493, p<0.001).

4.7.2 The effect of student action cycles on cognition

Although the original guide, (Wylam & Shayer, 1978), to the science reasoning tasks, (SRTs), developed by the Concepts in Secondary Mathematics and Science, (CSMS), team states that "*The pendulum*" task was designed to discriminate in the range of middle concrete operational, (<2B), to late formal operational, (3B), Piagetian sub-stages, an excel workbook, supplied to the author by professor Shayer for this study, restricted the top end of the analysis to early formal operational thinking, (3A).

Students were assessed prior to their engagement with student action cycles, (SACs), with the "*Volume and heaviness*" instrument, (SRT), and again, after completing two SACs, with "*The pendulum*" task, (SRT2). The results are compared in the following contingency table, (Table 4.7.2).

Table 4.7.2 The pre-student action cycle, "*Volume and heaviness*", (SRT) * post-student action cycle, "*The pendulum*", (SRT2) Crosstabulation, (n=49)

SRT * SRT2 Crosstabulation

			SRT2		
			2A/2B	2B	Total
SRT	<2A	Count	14	2	16
		% within SRT	87.5%	12.5%	100.0%
	2A	Count	4	6	10
		% within SRT	40.0%	60.0%	100.0%
	2A/2B	Count	6	9	15
		% within SRT	40.0%	60.0%	100.0%
	2B	Count	1	4	5
		% within SRT	20.0%	80.0%	100.0%
	2B*	Count	1	1	2
		% within SRT	50.0%	50.0%	100.0%
	3A	Count	0	1	1
		% within SRT	0.0%	100.0%	100.0%
Total		Count	26	23	49
		% within SRT	53.1%	46.9%	100.0%

On conducting bivariate analysis, a moderate and positive correlation was observed between the two science reasoning tasks, (r_p=0.425, p<0.002). Although there was evidence of some movement towards higher levels of cognition this change was found to be very small, (r=0.06).

A similar analysis was performed on the control group using the same SRTs. The results are compared in the following contingency table.

Table 4.7.3 The “*Volume and heaviness*”, (SRT) * “*The pendulum*”, (SRT2) Crosstabulation for the control group, (n=57)

SRT * SRT2 Crosstabulation

			SRT2			
			2A/2B	2B	2B*	Total
SRT	<2A	Count	8	3	0	11
		% within SRT	72.7%	27.3%	0.0%	100.0%
	2A	Count	6	5	0	11
		% within SRT	54.5%	45.5%	0.0%	100.0%
	2A/2B	Count	3	8	1	12
		% within SRT	25.0%	66.7%	8.3%	100.0%
	2B	Count	6	12	1	19
		% within SRT	31.6%	63.2%	5.3%	100.0%
	2B*	Count	1	2	0	3
		% within SRT	33.3%	66.7%	0.0%	100.0%
	3A/3B	Count	1	0	0	1
		% within SRT	100.0%	0.0%	0.0%	100.0%
Total		Count	25	30	2	57
		% within SRT	43.9%	52.6%	3.5%	100.0%

On conducting bivariate analysis, no evidence of a difference between the two sets of results was observed, (r_p=0.221, p<0.098).

A further analysis was performed on a larger sample to compare the two science reasoning task allocations of Piagetian sub-stages, where students were assessed with “*Volume and heaviness*”, (SRT), and then in the subsequent class with “*The pendulum*”, SRT2). The results are displayed below.

Table 4.7.4 "*Volume and heaviness*", (SRT) * "*The pendulum*", (SRT2) Crosstabulation for a representative sample of students, (n=204)

SRT * SRT2 Crosstabulation

			SRT2				
			2A/2B	2B	2B*	3A	Total
SRT	<2A	Count	30	9	0	0	39
		% within SRT	76.9%	23.1%	0.0%	0.0%	100.0%
	2A	Count	25	15	1	0	41
		% within SRT	61.0%	36.6%	2.4%	0.0%	100.0%
	2A/2B	Count	25	25	1	0	51
		% within SRT	49.0%	49.0%	2.0%	0.0%	100.0%
	2B	Count	19	32	6	1	58
		% within SRT	32.8%	55.2%	10.3%	1.7%	100.0%
	2B*	Count	4	7	1	0	12
		% within SRT	33.3%	58.3%	8.3%	0.0%	100.0%
	3A	Count	0	2	0	0	2
		% within SRT	0.0%	100.0%	0.0%	0.0%	100.0%
	3A/3B	Count	1	0	0	0	1
		% within SRT	100.0%	0.0%	0.0%	0.0%	100.0%
Total		Count	104	90	9	1	204
		% within SRT	51.0%	44.1%	4.4%	0.5%	100.0%

On conducting bivariate analysis, a moderate and positive correlation was observed between the two science reasoning tasks, (r_p=0.321, p<0.001).

4.7.3 Piagetian sub-stages and examination performance

In the literature review, (section 2.3.5), a linear relationship between the 'mean Year 7 school intake (percentile)' and 'mean GCSE grade', identified by Adey and Shayer, (2002), in support of the value-added effect of their cognitive intervention strategy, was discussed. In this study the Piagetian sub-stages for all students who had been assessed with the "*Volume and heaviness*" science reasoning task, (SRT), were compared their junior certificate performances in English, mathematics and science to identify whether a similar relationship was observable. The results are displayed in Appendix XIII.

Chapter 5 – Discussion

5.1 Introduction

The literature review for this thesis, and the author's teaching experience, provide an 'illustration' that might help make order from the numerous pieces of data that have been collected and presented in the results section that precedes this discussion, much like the picture on the box of a jigsaw puzzle and its contents. The analogy is a useful one in that, until the jigsaw has been completed, one cannot be sure whether the puzzle matches the picture, or even if all the pieces are present.

A common jigsaw puzzle solution strategy would be to first separate out all the edge pieces, to provide an outline, and then to fill in what is left. This chapter attempts to do just that, in the hope that at the end the puzzle pieces produce a picture that is a coherent image which might, or might not, match the illustration that formed the basis for this research.

What follows then, is a discussion of the results from the previous section and their relation to the research questions, corresponding findings and the conceptual framework derived from the literature review. It is divided into three sections, where each of the research questions is addressed separately. In Chapter 6 the key findings of this and the previous chapter will be brought together in summary.

5.2 Painting the picture

This section of the discussion is an exposition of the exploratory research that was conducted in an attempt to answer the first research question:

> How closely do specific pedagogical approaches align with students' perceived educational needs and attitudes towards science?

Numerous aspects of the students' reported experiences are brought together to attempt to paint a clear picture of the how the early years of secondary education in Ireland match the perceived needs of the child.

5.2.1 Crisis at age thirteen, fourteen, fifteen...?

If the educational experiences encountered by students are stimulating and match their level of cognitive development, (section 2.3.3), then it might be expected that there could be the potential for maximal, positive engagement with the curriculum. The literature review however, has outlined a number of studies that indicate a significant spread in the reasoning ability of students within any classroom, from 8 to 12 years, and also that there could be a lower level of processing of reality, (Shayer & Ginsburg, 2009, p.77), than might be expected. The literature review also highlights several studies that report an increasing decline in student motivation coinciding with a progression through the system from primary to secondary level; and from first to sixth year. A number of explanations for this have been proposed; some relating to physiological or psychological development, and others to a change in the locus of control, driving out intrinsic motivation and replacing it with compliance to the examination system for accreditation. The primacy of exams has been discussed at length, under the heading of diploma disease, and certainly the evidence from the previous chapter would seem to concur with this as a powerful force for change in terms of motivational focus. But what does the data from this research indicate in terms of changing attitude to school with age?

By first looking at the ‘how I feel about school’, (HIFAS), survey results, to identify alterations in orientation from first year onwards, and then by listening to the student voice, through comments in focus groups and suggestions on survey sheets, it may be possible to flesh out some of the external influencers for Vygotsky’s ‘crisis at age thirteen’; if it exists in the twenty-first century Irish classroom.

Only five of the HIFAS statements showed a significant change in orientation between first year students and their older peers, and these relate to the ease of distraction, propensity for challenge, workload, curriculum content and creativity. Two other statements, concerning learning outcomes and reflection, led to discernable differences only in examination years.

5.2.1.1 Distraction

Two statements from the 'how I feel about school', (HIFAS), survey have been grouped together under the collative heading of distraction; although these ask the students about their position on two different mind-states, namely mind wandering, (HIFAS 9) and distraction, (HIFAS 19). Both of these are attention failures, which may affect performance, but a difference lies in that mind wandering is typically an introspective and possibly creative activity whereas distraction is a disruptive response to stimuli in the external environment. Distraction may be focussed, in that energy is expended in concentrating on the wrong thing at the wrong time, or aimless, where a cognitive overload results from too many distractants competing for attention at the same time, drawing the individual away from the task at hand. When one is mind wandering there is no directed focus of attention and the free thought that is associated with this can be enjoyable, psychologically restorative and creative. The student responses to different ways of learning from the Student Review of the Science Curriculum, (SRSC), rated looking at videos moderately useful and effective but highly enjoyable, whereas research with university students has shown that mind wandering rates increase when watching videos of lectures compared to the live event, (Wammes & Smilek, 2017); this last observation is at odds with the findings of Bishop and Verleger, (2013, p.3), who argue that video lectures are as effective as in-person lectures, (p.5).

There is research, (Dixon & Li, 2013, Farley et al., 2013, Varao-Sousa et al., 2018), that indicates that the effects on cognition are not equal between the two forms of attention deficit and that distraction may compromise memory much more than mind wandering; where in the former, the individual is completely off task, but in the later they might just be playing with different combinations to a solution. It is suggested that causes of distraction are hunger, or the exciting conversation of peers, while mind wandering might result from a disinterest in the task or tiredness.

In this study, 59% of first year students, (n=111), self-reported that they found their mind wandered a lot when doing schoolwork, (section 4.2.4), increasing to 68% for second and third year students, (n=170), and to 81% for those in sixth year, (n=76); the percentage of students strongly identifying with this, by choosing the 'very much like me option', more than doubled from 13% at the start of the secondary experience to 30% at the end.

A similar pattern was found when students were asked to position themselves with regard to, "I am not easily distracted from work", (HIFAS 19). Here 45% of first year students, 51% of second and third year students and 69% of sixth year students disagreed with the statement; and the percentages for those who selected the most extreme, 'Not at all like me', option rose from 14% in first year to 31% in sixth year.

If these statistics are applied to a typical classroom of twenty-four first year students it would suggest that twelve of them are sporadically paying attention while three of them have switched out for the majority of their time. In a similar sized class of sixth year students, eighteen would be showing attention deficit while seven would be involved with, or thinking about, activities unrelated to class for a significant proportion of the lesson.

The increase in mind wandering and ease of distraction, if you like, the flipping of the default setting of curious and self directed learning, mirrors the decline in interest from Harter's findings, (section 2.2.11).

When students, (n=324), were asked to consider circumstances that encouraged mind wandering, in terms of loss of concentration and distraction, (Table 4.2.4), well over a quarter of them, (n=94), reported that noise, more than anything else, was the main instrument of distraction. This was very closely followed by the draw of their phone, or other devices, (n=68). Friends might be reassured to note that they were reported as slightly more distracting, (n=62), than boredom, (n=52), while the only other distraction that made it into double figures was hunger, (n=10). To conclude then, by far the majority of distractants identified in this study align with the category of disruptive external environmental stimuli, as reported in the literature.

Factors that affected concentration were reported as more diverse. The most commonly identified affecter was 'boring work', (n=58), which was very closely followed by thoughts of home, their social life, or sports, (n=49). Being overworked, along with 'the teacher going on', (n=42), were marginally more common responses than those items that had been identified previously as distractants; namely friends, (n=32), a phone or device, (n=29), hunger, (n=29), and noise, (n=26).

When a focus group of second year students was asked about mind wandering the following conversation resulted:

Student A

> Well, like, of course you get bored, like, cos, no wait but, like it's just talk, talk, talk, like, and you've just had it in the last class and you'll get it in the next, like….

Student B

> Yes, I agree with [student A], specially like if it's the last class, or the afternoon, or you're hungry like ….

Student C

> can't stand it when it's just blah, blah, blah, blah….

Student A

> and then like you get, "Let's do a Twitter"…. [laughter]…. on like what the main character in the story was thinking", and you go like deh Miss

5.2.1.2 When the going gets tough…

Another noticeable change in attitude between first year students, (n=112), and the rest of the school appeared in their responses to the 'how I feel about school', (HIFAS), survey statement 17; 'When work gets hard I give up or only study the easy bits', (section 4.2.3). Twenty-four percent of first year students were in agreement with the statement but this rose to 46% for sixth year. The percentage of students who expressed the opinion that this was 'Not at all like me' dropped from 38% to 16% over the same interval. The question is whether the self-reported decreases in perseverance represent a motivational deficit, (Lepper et al., 1997), or a possible trade-off in curiosity by older students in favour of a preference for the more manageable curriculum content, (Loewenstein, 1994); whether they represent data in support of the principle of 'learned helplessness', (Seifert, 2004) or indeed, all of the above.

Motivational deficit was certainly apparent in comments from focus group sessions such as, “Why do we have to know all that stuff, when am I ever going to need Pythagoras in real life” and “Science is just boring. Why can’t we do all experiments instead?” Indeed, the ‘why do we need to know this?’ mindset appeared to be a far too common indicator of a lack of intrinsic motivation in the majority of the *traditional* chalk-and-talk classrooms from this study. But then, this might come as little surprise considering the data from the ways of learning, (WLQ2), questionnaire, (section 4.3.2), that indicated that a significant proportion of student time was spent being talked at, rather than being engaged in activities that might foster intrinsic motivation. Instead of weighing the educational value of instruction against practical work, in terms of covered curriculum content, it might be favourable to respond to the frequent calls of, ‘Can we do a practical today?’, or ‘Are we using Bunsen burners today?’, in the affirmative as the motivational benefit of *fun* might be similar in effect to the ‘magic markers’ of the Lepper et al. study, (section 2.2.3).

Harter’s assertions, (Figure 2.6), that there is evidence that formal education promotes motivational deficit by stifling intrinsic motivation, with respect to curiosity and interest, in preference for teacher approval and grades, was apparent in a number of the responses in this study; but there was also contrary evidence in terms of the results from the Trends in International Mathematics and Science Study, (TIMSS), questionnaires, (section 4.4). The results from this author’s research indicate that the change from junior certificate, with its rigid learning outcomes and mandatory experiments, to the more open statements of the specification for junior cycle science, (SJCS), yielded a concomitant increase in the number of students affirming that they enjoy learning science; a 68% to 89% increase for girls and a 55% to 72% increase for boys.

The effects of being overwhelmed by the amount of work that one is expected to complete should also be considered when examining the causes of motivational deficit; especially in light of the 19% decrease, from first to sixth year, in the number of students who reported themselves as being up to date with their schoolwork; according to HIFAS statement 7, (Figure 4.2.38-4.2.40). Are students overwhelmed with the amount of work they have to do and mentally tired before they even enter class? Do they strive for the easiest path in an attempt at effective time management? Is this what is regarded as motivational deficit?

It is easy to put a cause of motivational deficit down to laziness, tiredness or even to a twenty-first century societal and cultural shift to 'swipe-right', text-speak, emojis and the media replacement of evidence-supported fact by influenced opinion, but it must still be hard to feel motivated if one does not regard oneself invested in the educational process. There is evidence from this study that indicates this to have been the case as, according to the results from HIFAS statement 23, (Figure 4.2.3), 60% of the school population sensed that they had little control over their learning and, in addition, a lack of curiosity and interest in a challenge was reported by a further 40% of students, (Figure 4.2.28). It would appear that a significant proportion of students were placed in the zones of relaxation and anxiety on Day's curiosity curve, (Figure 2.5), through being told what to learn. This spoon-feeding approach to education of ‘tell me what I need to know’, is encapsulated in HIFAS statement 11, (Figure 4.2.1), and was subscribed to by the 76% of those asked, (n=461).

It is more than possible that the changes in response to HIFAS 17, (Figure 4.2.13), as students from this study progress through the school, represents a trade-off in curiosity for more manageable curriculum content; as first proposed by Loewenstein (1994) and supported by the work of Lepper at al. (1997). It could also be that the teaching styles students encountered for the delivery of content heavy, leaving certificate syllabi were disagreeable with regard to intrinsic motivation. Those students who expressed a lack of curiosity and a preference for teaching-to-the-test may have failed to realise that without a wider context, information is unlikely to be effectively assimilated as knowledge with understanding; that is to say, wisdom.

Learned helplessness, potentially linked to feedback as grades rather than comments on how to improve, (section 2.2.4), may also have been responsible for the observed drop in perseverance. Indeed, when students have come to accept failure as a too frequent result of their efforts, without the skills to deal with such setbacks, then probably for them, to quote one of many Homer Simpson aphorisms, “trying is the first step towards failure”. The results clearly showed that there were still signs of diploma disease, (section 2.2.12), where it didn’t need to be. The advocacy of learning to learn (L_2L) strategies, and the fostering of enjoyment of the subject through ‘curiosity in thoughtful and deliberate action’, (NCCA, p.1) so enshrined in the junior cycle specification, had apparently not yet been universally adopted by all stakeholders in the process.

5.2.1.3 Workload

Statement 7 on the how I feel about school, (HIFAS), survey, (section 4.2.7), asked students to respond to 'I am up to date with all my school work'.

First year students responded most positively to this with 89% in concurrence, but a marked decrease was noted from second year onward culminated in only 70% agreeing with the statement by sixth year. In addition, the percentage of students who reported that the statement was very much like them more than halved, from 36% to 16%, while those who chose the 'Not at all like me' option, indicating that they felt they were not keeping up with their studies, had tripled, from 4% to 13%. This same drop was observed in responses to "I always do my homework", (HIFAS 29), where the decline in students agreeing, from first to sixth year, was from 85% to 78%.

One explanation for this change is not hard to find, and lies more with a pathology of the system than a change in work ethic; although the latter cannot be disregarded as an influencing factor. The school homework policy states that students in first and second year 'should be doing eight hours of homework each week' but in sixth year the expectation increases to 'approximately 20-25 hours per week'. The policy is also explicit in that it states that homework 'is vital for examination success'. It is little wonder that students report difficulty in staying on top of their workload, or that the comments regarding the amount of homework set become increasingly common through the later years. It could be argued that the prescriptive nature of completing work that has been set for compliance with school policy lies as an uncomfortable bedfellow with the proposition that secondary education should develop skills associated with learning autonomy, (LA).

5.2.1.4 Curriculum content

Two statements in the how I feel about school, (HIFAS), survey explored student impressions around course load and content. Once again, there are parallels between the results from this survey and those of the Student Review of the Science Curriculum', (SRSC), (section 2.2.13). For both HIFAS statements, the distributions of responses from first year students were markedly different from older students.

In first year, 69% of students disagreed with the statement, 'In my opinion, most of what is taught in class is not worth learning', (HIFAS 27), but by sixth year, this proportion had dropped to 38%; and the number that proclaimed that this stance was not at all like them had dropped from 32% to 5%, whereas the numbers for those who were in strong agreement, by choosing 'Very much like me', had quadrupled from 5% to 20%.

The second HIFAS statement, (HIFAS 40), addresses teacher delivery, in terms of clear and related statements of learning, as much as it does curriculum content. When the responses were analysed it was found that only 41% of first year students disagreed with, 'Much of what I learn seems to be unrelated bits and pieces that I can't see the purpose of knowing', and this had dropped to 25% by sixth year; conversely, 9% of first year students rising to 23% in sixth year very strongly identified with this.

It is important to bear in mind that there are other factors that impact on students' perceptions in relation to curriculum content, not least of which is the fact that from first to third year, students are engaged with junior cycle as opposed to senior cycle, (leaving certificate), for fifth and sixth years. There is a slight degree of flexibility of study, in that first year students spend four weeks sampling before selecting two subjects to add to the other twelve that are compulsory components of their core curriculum. English, maths, Irish, (unless the student has a language exemption), and French or German are core subjects for senior cycle students, (in addition to religious education and social, personal and health education, (SPHE)), and to these they select three additional courses from an option list of sixteen. This minor freedom to select subjects of interest to the individual, (or points value), may have positive or negative influences on the responses given; depending on whether the choice that was made has matched expectations.

5.2.1.5 Creativity

Statement 15 in the how I feel about school, (HIFAS), survey asked students' opinion on whether they enjoyed the creativity of project work. The reason for the inclusion of this statement was to link to the rationale section of the specification for junior cycle science, (SJCS), where science is described as a 'creative human endeavour', (NCCA, 2015, p.2). It is important to mention that the HIFAS survey was conducted across the school in many subject areas simultaneously and therefore the responses do not, and should not, necessarily reflect on science *per se*.

First year students were in greater agreement with this statement than other year groups with 77% of students affirming the statement in comparison to 55% for sixth year. Those in strong disagreement rose from 6% to 18% over the same timeframe. Regardless of the 22% decline in endorsement of project work, a slight majority of sixth year students still identified this as a preference. It is possible that student responses to the statement may have differed in terms of whether they were in approval of project work or agreeing that it facilitated creativity.

5.2.1.6 Increasing motivational deficit?

The previous five sections have discussed age related differences in the manner by which students identify with statements focussing on distraction, challenge, workload, curriculum content and creativity, in an attempt to identify causes for motivational deficit, the protestations of youth, that was mentioned in section 2.3.6; and led to the initiation of this research.

Hard though one might look, the data from this study does not paint the same picture of progressive disaffection that was observed in some of the junior certificate students prior to 2016 and claims that 'science is boring' and impossible to master have not been heard by this author since the introduction of the specification for junior cycle science, (SJCS). How then do students view their junior cycle and leaving certificate experience?

5.2.2 Is diploma disease is endemic in Ireland?

At the start of the twentieth century, in his inaugural address as rector of Aberdeen University, Huxley turned his attention to examinations and compared them to 'fire', stating that they were a good servant but a bad master. He was concerned that the constant striving for accreditation that he observed reduced the intellectual capacity of students such that the pursuit of real knowledge was sacrificed for the passing grade. He pronounced that, 'They work to pass, not to know; and outraged Science takes her revenge. They do pass, and they don't know', (Huxley, 1904, para.75).

This is the same argument that was alluded to on the first page of this thesis, where it was reported that the National Council for Curriculum and Assessment, (NCCA), had perceived a divergence "between the intended curriculum and the enacted curriculum", (NCCA, 2013, p.1), in that classroom instruction was largely oriented towards the rote memorising of factual information to pass examinations, without creativity, collaboration, curiosity, deep understanding or the application of skills. The authors of the NCCA report regarded the cause of this as a "misalignment" between teaching, learning and assessment strategies such that the differing aspects of these key curriculum components led to a lack of coherence of purpose; a view reiterated in the Hyland report, on the proposed modified design for leaving certificate science syllabi, where she wrote that:

> the problem of rote-learning and memorisation lies in the type of assessment we have in Ireland – 100% written terminal examination; and inadequate congruence and alignment between the desired learning outcomes of a syllabi, the approach to teaching and learning and the modes and techniques of assessment.
>
> (Hyland, 2014, p.38)

This view had previously been expressed by Dore (1997), (section 2.2.12), who described the 'ritualized process of qualification-earning' in his diploma disease thesis. Additionally, there is evidence from other research, (Shepard & Dougherty, 1991, Koretz, 2008), that high-stakes testing leads to a back-wash effect; specifically where assessments determine the pedagogical approaches that are valued by students and their parents to be those that merely inculcate a knowledge, (recall), of facts.

It could be argued that the requirement to meet the perceived needs of the student, and their parents, in this accreditation race has led to the establishment of a grinds culture where multi-million euro businesses, such as the Institute of Education, act as agents for diploma disease; by providing places for students to be introduced to the finer arts of how to achieve top points in order to beat the examination system. In places such as these, learning is sharply focused on developing recall skills through the lens of assessment.

In order to gauge the perceptions of students from this study about the role and purpose of the educational or examination processes, a number of statements probing these were included in the how I feel about school, (HIFAS), survey. Students' responses largely supported the diploma disease thesis as described below.

The epitome of diploma disease has to be the statement, "I only want to learn stuff that will come up in exams.", (HIFAS 8), (section 4.2.2). The results from this study, (n=462), indicated that in a typical classroom, nineteen of the twenty-four students present would ascribe to this view; and only two, at most, would be open to a more holistic education. Considering the move away from the moderately restrictive learning outcomes of the junior certificate science syllabus, (JCSS), that lent themselves to rote learning practices, to those of the specification for junior cycle science, (SJCS), that advocate a freer interpretation, there is a potential for even greater curricular fragmentation in terms of regard for what is regarded as of most educational worth.

The observation that the student responses are so static over the junior cycle, junior certificate and leaving certificate divides raises the question as to what is the major instigator of diploma disease? Does it come from the students, who wish to best their classmates, impress their teachers or show filial piety to their parents? Do teachers overegg the importance of performance indicators by imposing and reporting on these all too regular, regimented assessments? Or does the impetus come from the parents, who are more clued in to the importance of 'a good set of results that will open doors'?

That students in first year suggested survey statements for inclusion, related to Christmas assessments, so soon after starting their secondary education indicates that the message of junior cycle has not yet been embedded across all curricula and specifications. In addition to this, the cry from the heart of the fifth year student, who expressed the view that “exams…[are] not the be all and end all of your life like teachers keep stressing”, clearly indicates that, for at least one individual in the system, the lack of coherence of purpose, reported by the NCCA and Hyland, is all too evident.

The statement, “I prefer tests that ask me to write down facts that I have been told, to tests that ask me to work something out”, (HIFAS 20), was included to discriminate between the value placed by students for propositional knowledge, the factual memory of ‘knowing that’, from either procedural knowledge, the ‘knowing how to’, or epistemic knowledge, the ‘knowing about’. Three quarters of students sampled, (n=464), eighteen out of a class of twenty-four, concurred with the statement, identifying propositional knowledge as their preferred option.

When the analysis of preferences in HIFAS 20 was extended through the interpretation of the results from HIFAS 2, “I don’t care whether I understand my work as long as I remember enough to get good marks in tests”, (n=469), the collected data indicated that half of an average class, (twelve students), prescribed to this view. These twelve would have been most familiar to Huxley in that they are undoubtedly working to pass and not to know. However, the results should not be all that surprising as it appears “there is no new thing under the sun”, (Ecclesiastes 1:9 KJV), when it comes to education. Students are content to scribe, to copy verbatim or to acquire photocopied notes in the belief that this *is* learning as observed by Slosson, at the turn of the twentieth century, when he wrote this about his experience:

> Lecturing is that mysterious process by means of which the contents of the note-book of the professor are transferred through the instrument of the fountain pen to the note-book of the student without passing through the mind of either.
>
> (cited in Miller, 1927, p.120)

Somewhat reassuringly, when students, (n=465), were asked to evaluate their position in regard to problem solving, the majority agreed that this was a valuable skill that outweighed the ability to simply recall a solution. Only 25% of respondents felt that "it is more important to know the answer than how to work it out", (HIFAS 16), or to put it another way, "learning the skills to solve a problem is more important than knowing the answer", (HIFAS 35); to which 91% responded in the affirmative, (n=450).

When asked about the apparent disparity between the results just mentioned, (those that would appear to show that students rate the ability to problem solve highly and those that indicate that rote learning content is more greatly valued), students, (n=262), almost unanimously, (94%), commented that, in responding to the statements, they had been considering their mathematics studies. Further probing revealed that by and large students interpreted problem solving as a verb, (as in to problem-solve), with the ability to apply a particular regime or strategy, such as the equation of Pythagoras' theorem after a trigger prompt, rather than open ended deductive reasoning. They reported that they felt these *skills* were learned in the same way as *facts* in that they were memorised and practiced. The intention behind the statements had been to probe for the application of transversal skills, but it was evident that the students' interpretations of the statement wordings were at odds with this.

When considering diploma disease, the effects of contextual and subliminal stimuli should not be ignored. The following image is a photograph of two posters juxtapositioned on the wall in the first year common area.

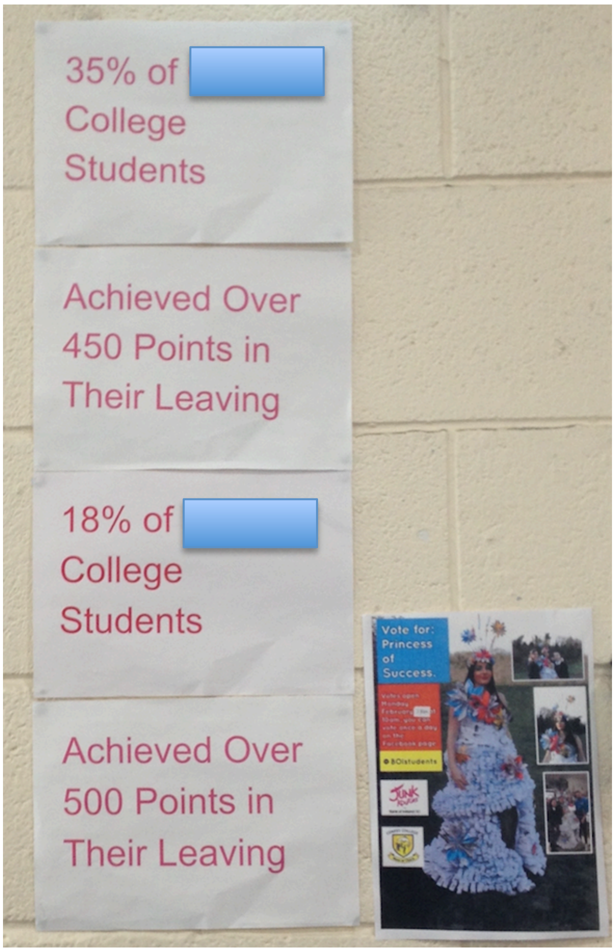


Figure 5.1 A photograph of posters displayed in the first year common area

The pages to the left, in the image, send a very clear message to students that points have value; even possibly before some of the first years, who have between five and six years of schooling ahead of them before they sit their leaving certificate examinations, (which is roughly equivalent to their total time to date in formal education), realise what these points are. The use of the word 'achieved' also carries implied value.

To the right, the much smaller poster advertises one of the school's entries in the Bank of Ireland Junk Kouture competition, an event for young designers to show their talent in crafting outrageous fashion from recycled materials. This is a high profile, glamorous, and widely publicised event that attracted 1,500 entries, from secondary school students in 2018, which were judged by media 'superstar' Louis Walsh, from Ireland's Got Talent and the XFactor, and his panel of celebrities. As part of their prize, the five regional finalists from this competition were flown to the Cannes film festival to showcase their designs in front of the World's paparazzi before continuing on, by helicopter, to Monte Carlo. The couture being modelled in the photograph is entitled 'Princess of Success', and consists of a dress and accessories repurposed from leaving certificate exam papers; linking possibly, success with the exam process.

Historically, one might look for the Irish origins of diploma disease in the intermediate education act of 1878 that introduced junior, middle and senior grades of public examination. In a model that came to dominate the Irish secondary system from that time up until Independence in 1921, the extent of public funding for any particular school was dependent on the quality of its students' examination results. In 1922 the

Department of Education was established and the intermediate and leaving certificates replaced the previous triplet of examinations; however the inspectorate still set the programme of study such that terminal examinations continued to dictate the educational experience of the students. Along with the change of structure, the performance-related funding of the previous system was replaced with capitation. It could be argued though, that the premise, 'best schools get the best results', had already become so ingrained in the Irish psyche that parents, who were able to, would preferentially select schools that rated highly in terms of exam performance, thus increasing enrolment numbers and simultaneously, the size of the capitation grant. This in turn would have the circular effect of focussing attention on the institutions' terminal performances relative to other schools in the locale, published in league tables, and establish the philosophy of 'teaching-to-the-test'.

Annual school league tables are still published today, under headings such as 'The top 100 schools', or 'The best secondary schools in Ireland', along with 'feeder school maps' that chart the school-to-institution progression as a percentage of the leaving certificate student population. Nowhere in these performance indicators though are measures of value-added or of talent and skills development.

Of course diploma disease is not, and never was, restricted to Ireland. Looking to America, for a comparable example, one only has to consider the minimum competency testing movement of the 1970s. Prior to this time, little regard was paid to standardised tests of achievement other than to generally monitor local and national trends. In fact, as reported by Gosling, (1967, p.121), such test were regarded with such little importance that teachers were almost never asked to consider providing special preparation, or alter content, for them by students, management, parents, or the local authority. This changed with the educational reforms of the 1980s, when standardized testing became regarded as a compelling method for driving 'improvements' through instructional pedagogies, (Popham, 1987); where performance, in terms of the efficiency and efficacy of instruction, was gauged by test results. It was Popham's view that if the assessment product was regarded to be of sufficiently high-stakes then it would act as an 'instructional magnet' for teaching-to-the-test. Opponents at the time, in the same cry that is heard today, argued that this would lead to a fragmented curriculum that lacked coherence. Unsurprisingly, examination results were seen to increase; but as Shepard, (1991), observes, it was possible 'for test scores to go up without there being a commensurate gain in learning' and high-stakes testing regimes can lead to inflated and spurious results. She quotes Cannell's, (1987), findings that all 50 states of America claimed, <u>at the same time</u>, to be above average. Cannell, (1988), comments that even after taking the different statistical reporting methods employed into consideration, the tests of elementary, (primary/national school), level students allowed '90 percent of the school districts in the United States to be above average', (p.2). Shepard also asks why it is that, taking the overall dramatic improvement at elementary level as read, no evidence of this improvement is evident by the time they reached secondary school, (p.7). The net result of teaching-to-the-test is a reduction in higher order thinking skills. The preceding paragraph illustrates just how easily the value that is put on exam performance by external agency can lead to grade inflation to confirm that self-same performance. In support of this, the results from Shepard's, (1991), research establish that in the 100 schools they studied, (n=360 teachers), 79% reported 'substantial' or 'great' pressure to increase performance by school administration and 66% responded that the pressure was also imposed by media and local education authorities. This external pressure to teach-to-the-test, to boost standardised scores, led to teachers reporting, (Shepard & Dougherty, 1991), that the excessive time spent on exam preparation distorted curricula and diminished content.

In summary then, and in partial answer to the question as to how closely specific pedagogical approaches align with the perceived needs of students, one has to consider the results of the 'how I feel about school', (HIFAS) survey that support the diploma disease thesis; whether these match the aims and goals of the specifications and curricula or not. With 80% of students reporting that they only desired to engage with examinable material, 75% wishing to learn facts rather than work out solutions, and 50% who were not concerned whether they understood what they were writing, just as long as it got them the marks, rote learning has to be the students' preferred pedagogy at secondary school level.

Unfortunately, as the ghost of Huxley's chains quietly rattle the words, 'working to pass and not to know', like the rumble of an old railway carriage on rickety tracks, the challenges a students meets as they move through the system become increasingly demanding, and diploma disease brings with it its inevitable consequences. Students who have rote learned to pass can be over confident in their abilities and make ill-advised option choices when it comes to progression to third level education.

In 2017, over 60% of Irish school leavers, (44,124), transitioned to universities, institutes or colleges, to join with those already undertaking full-time, part-time or remote courses, to swell the figures to 231,710 enrolments; equivalent to about 7% of the total adult population of the country, (https://hea.ie/assets/uploads/2019/01/Higher-Education-Authority-Key-Facts-Figures-2017-18.pdf). However, according to figures released by the Higher Education Authority, (HEA), an annual attrition rate, between first and second year, for university students of about 14% and 24% for technical colleges reduces the numbers that continue on towards graduation. The highest recorded dropout rates are for technical courses, with low entry point requirements, but high mathematical demand. Has the working to pass left the students with an ill prepared skill set for the rigours of academia?

The cognitive ‘readiness’ of a sample of these students for the demands of a university course was discussed in section 4.5.4, but the following illustration of learning without understanding, (one of many), comes from the author’s years of experience as a lecturer on junior cycle methodologies with second year trainee science teachers undertaking a professional masters of education, (PME), course at an established university.

During one session, the author observed a group of four students attempting to conduct an investigation, modelling the process of a classroom based assessment, the extended experimental investigation, (CBA-1 or EEI), that they would have to administer to second-year school students. They had decided to investigate how light intensity affects the rate of photosynthesis, but unfortunately, none of them had remembered to source pondweed, *Elodea*, or its equivalent, prior to the practical. Not to be thwarted by this, the group improvised and collected privet leaves, which they then proceeded to place in an empty beaker under an equally empty, upturned graduated cylinder. When asked what they were doing, they confidently responded that they were “counting the bubbles”, while pointing at their set-up. Further questioning elicited responses that they knew exactly what they were doing because they had been taught the practical in class many times, but also that they had never actually conducted the experiment; this is a mandatory practical on the leaving certificate biology courses that they should have all completed at their respective schools. The bubbles of oxygen that they hoped to observe, rising from the pondweed and collecting at the top of the graduated cylinder, never materialised, even when they eventually decided to fill the apparatus with water. Their privet leaves remained static and decidedly non-effervescent at the top of the graduated cylinder without raising the slightest shred of concern that there might still be something wrong with their procedure. They had clearly, by their own admissions, learnt to pass without understanding. Has then the system that has got them to university truly met their educational needs?

It is well to remember that diploma disease also affects the other portion of the school community, those that do not go on to further education. How well does the narrowed focus resulting from teaching-to-the-test and slavish adherence to marking schemes, in a points race they are not directly competing in, meet their needs for a wider education with skills for life outside the classroom?

5.2.3 Tell me what I need to know!

The literature review addressed motivation from a number of angles in an attempt to identify different concepts that might drive students in their learning but, as the previous section has highlighted, it appears that a significant proportion of the students from this study were simply extrinsically goal oriented towards certificate attainment. To all intents and purposes, for these individuals, the intrinsic desire to deepen knowledge and understanding appeared to be hidden or non-existent. Essentially, to adapt the old aphorism frequently attributed to the journalist Miles Kington, they were content in the knowledge that a tomato is a fruit, as this would bring with it examination points, but lacked the drive to develop the wisdom not to put one in a fruit salad.

Where then has the “manifestation of interest” and “affective engagement”, described by Sivan, or Piaget’s intrinsic motivation, driven by effective assimilation gone? Are we operating in a system dancing to the tune of Skinner’s operant conditioning, where students, like pigeons, ‘peck’ away at marking points to achieve their examination reward?

When students in this study, (n=452), were asked to rate their agreement with the statement, “It is more important to me to impress my teacher or parents by my success in exams compared to learning new skills”, (HIFAS 28), (section 4.2.1), over a third, (35%), strongly identified with this, approximately half, (51%), concurred and only around four, (15%), in a typical classroom of twenty-four individuals felt this did not to reflect their disposition.

This data appears to indicate that the desire for approbation is indeed a very powerful motivator with regard to academic endeavour, and that this is achieved, in preference, through performance, rather than mastery goals.

Positive feedback, from teachers or parents indicating that they are impressed with a student's performance, should feed into Maslow's hierarchy, (section 2.2.2), as this would indicate that the individual has achieved the respect of others; which is integral in generating those interpersonal feelings of belonging that epitomise the love need. Also reinforcing this explanation of student responses to HIFAS 28 is Vygotsky's proposition, that support and praise within the social dimension boosts motivation. Of course, Covington's self-worth theory, (section 2.2.8), with the conception that teenagers and adolescents largely equate achievement with ability, applies when accomplishments are recognised, and valued, by any other who is held in high regard. Ames reminds us though, that the normative assessment practices, extrinsic rewards and focuses on perfection, common in most educational establishments, are bound to automatically inculcate, through repetition, the desire for affirmation in the student population.

Whether academic success bolsters a student's self-conception through the praise it garners, or completes a social obligation to one's parents and teachers as described by

Ng, there is no denying that it has a powerful influence over the motivational mindset of the student in the classroom.

The breakdown of responses to the statement, (HIFAS 28), was puzzling, considering the experience of the students from this study where, by and large, the whole aspect of social approbation is undervalued through the establishment of long-term, rather than short, reward events; a biennial written report, a single parent-teacher meeting and an annual awards ceremony, where all students are recognised. With such long intervals between these events it must the satisfaction of informal praise that is more driving. However, as was mentioned in the literature review, if praise is not received, or given where it is not deserved, there is the risk that work is regarded with less value, the outcome is disowned, and reasons for poor performance are placed at the feet of the teacher; as in Maier and Seligman's, (1976), learned helplessness theory. It must not be forgotten that the affective function of formative assessment is to move the student from the subjective marker of 'I can now do this' to a position of demonstrating true competence and mastery.

Other than establishing that students relish praise, it was impossible to deduce from the results of the survey whether the frequency, or quality of praise events met with, or exceeded, the minimum of students' perceived educational needs.

Statement 11 in the 'how I feel about school', (HIFAS), survey asked for responses to "I like to be told what I am expected to learn in class.", (section 4.2.1), to which 76% of the respondents, (n=461), replied in the affirmative. On further analysis it became clear that students had multiple interpretations of the purpose of this statement. Some, (13%), linked the phrase to displaying explicit learning outcomes for each class at the beginning of a session to formatively signpost the direction of learning, while others, (32%), regarded it from a summative perspective as an opportunity to 'checklist' their items of learning for upcoming assessments. A third group were less personally invested with the process and reduced the statement, in terms of its meaning to, 'I like to be told what to learn'. A successful lesson, for these students, was described by some of them as one where they "got all the notes down off the board" and had a record of their homework.

It is the 8% of students who reported strongly that the statement, "I like to be told what I am expected to learn in class.", did not represent their views that are of most interest to the author. If you are not explicitly told what you have to know then the doors are opened for exploration, inquiry based learning, and flow associated with challenge. This was the view of some of these students who commented that, "I like to find stuff out for myself", or, "It's fun to have a challenge to work it all out", and also, "It's like boring if you put that.. [the learning intentions].. on the board cos then you might just not be there cos you've got it already".

When the responses to this statement, (HIFAS 11), are considered in conjunction with the previous one, (HIFAS 28), then the possibility arises that being told what to learn, and then being assessed on that information, provides an easier method for meeting the threshold level for approbation desired by the students in this study.

Analysis of the responses from students, (n=458), presented with “I often get confused as to what I am expected to learn in class”, (HIFAS 22), showed that well over half, (62%), were in agreement. This might indicate that despite their position on the previous statement, (HIFAS 11), that affirmed a wish to be told what they were expected to learn, a large proportion of the cohort felt that this desire was not being met.

Further questioning identified some of the causes of student confusion. Three groups of responses emerged; one group focussing on the wording of the learning outcomes, (21%), another, (18%), on the lesson’s content in relation to assessment and a third, (23%), who were very vague in their responses and unable to formulate, or articulate, clearly what it was that caused them confusion. Typical responses to ‘what do you find confusing?’ included, “everything”, “what do you mean?”, as well as general references to curriculum items such as, “equations”, “doing experiments”, and also “the way teachers talk”, (spelling as original).

The importance of autonomy, competence and relatedness in fostering intrinsic motivation were identified by Ryan and Deci, in their self-determination theory, and later works, (section 2.2.4). Considering the extrinsic motivators of diploma disease and the student buy-in to the points system, it might come as no surprise that those that were surveyed, on the whole, regarded the teacher, rather than themselves, as responsible for their exam success. When faced with, “I believe that exam success depends more on the teacher I have than on my ability”, (HIFAS 25), 70% of all students polled, (n=463), agreed; with eighty students, (17%), stating that they identified very strongly with the position.

When quizzed as to why this was, students responded, "they… [the teacher]… make all that stuff into stuff you can understand." and "how are you supposed to find out what's important to remember for exams without a good teacher that tells you"

It is not only students who imagine the involvement of some arcane ritual in the process of translating curriculum content into the lay speech of the classroom. The Hyland report, (2014, p18), includes the following comment from a transcript of correspondence between the chairperson of the Irish Science Teachers Association, (ISTA), and the National Council for Curriculum and Assessment, (NCCA) in reference to the proposed learning outcomes in the draft syllabi for leaving certificate sciences:

> 'The essential problem with the proposed draft syllabi is that they simply contain a list of learning outcomes with no indication re depth of treatment or range of subject knowledge associated with these learning outcomes…Even highly experienced science teachers at our ISTA Council meeting found problems with interpreting many of the learning outcomes.'
>
> (Hyland, 2014, p.18)

It would be fair to say that, in general, the link between any curriculum and the students' programme of study lies with the learning outcomes that are iterated in class. The responsibility for unpacking each course lies with the subject teacher and, more importantly, the learning outcomes should be regarded as the threshold for student understanding. Students cannot easily unpack bald learning outcomes. This is one of the dilemmas of junior cycle, where the skills of 'learning how to learn', (LH2L), (section 2.4.6), require open or semi-structured activities, rather than restrictive, guided methodologies. This then raises concern over the later transition to leaving cycle, where learning opportunities are much more closed and specific due to the requirement that the student be fully prepared for the high stakes terminal examinations. Of course, with a plethora of study guides and textbooks currently available for the learner, it seems anomalous that the number of students claiming that their grades depend on their teacher is so high. Might this be an indication that students are abdicating the responsibility for their performance in line with the position of learned helplessness? Has too frequent spoon-feeding meant that students are unwilling, or unable, to work as autonomous learners? Certainly the grinds culture, with its 'no-pay-no-play' attitude to education, has had a knock-on attitude to free schooling for some who voice the opinion that "if it is not worth paying for, it cannot be much good."

A further statement probing students' perceptions around the power dynamic of the classroom asked for responses to, "I often feel I have little control over my learning.", (HIFAS 23). This statement was interpreted by students in terms of the 'what' and the 'how', with the larger proportion, (68%), reading it with regard to the latter. Only 40% of the students polled, (n=462), considered that they were in control of their learning, while nearly a quarter indicated that, for them, their impression was that this was very much not the case.

When considering the ‘what’ aspect of learning, it was evident that students identified this as the body of information, with associated skills, that, in its entirety formed an immutable curriculum that they were required to engage with. The depth and detail required for coverage was, to them, as detailed as a travel itinerary. Success in science involved, in their expressed opinions, visiting all the required stops and remembering enough detail to pass the end of topic assessment tasks. Whether this stance changes with the embedding of the framework and specifications for junior cycle remains to be seen.

Focus group discussions on the ‘how’ of learning revealed that learning was largely equated with lesson-time, rather than the process or outcome in itself. Students articulated that they felt that lesson foci were the teacher’s prerogative and that the methods, direction and speed at which class-time moved towards achieving these was generally outside their control, or indeed influence. This is very reminiscent of the description given by Wiliam, (section 2.4.2), of his impression of the difference between summative and formative assessment. Students voiced that sometimes they had been left behind as the theme of the topic had moved on without them having a clear grasp of material covered; to paraphrase Wiliam, they were like discarding passengers left adrift at whatever location had been reached before the pilot moved on to the next destination.

Some students expressed concern that for activities, such as the classroom based assessments, (CBAs), the scope of inquiry was set too broad; which supports the comments about the perceptions of teacher misbehaviour by giving too many options, discussed in the literature review, (section 2.2.5). They remarked that at times the learning outcomes from the lessons were not clear, or consecutive with other content that they had been involved with. This was particularly apparent when engaging with open-ended investigations of the inquiry based learning, (IBL), variety, as part of the skills development for the CBAs. Here, too often, the purpose of the activity, and the learning outcomes, were reported to be conflicted, in that students regarded the two as separate, and focussed on one <u>or</u> the other. Several students expressed the wish for more rigid instructional guidance rather than a loosely directed constructivist approach, particularly at the stage where they were developing their skills as novice researchers. Flawed experiment designs, non-fair testing, inaccurate data collection and incomplete records of data were a common outcome where the task set was too open-ended, and less than ideal choices were made, which was later seen in the selection of titles for CBAs.

The sub-optimal selection of an investigation for a CBA was particularly apparent as students struggled to identify a task that was suitable. The 'egg drop' experiment, that many had undertaken in national school, with variations on the theme of protecting an egg from shattering when dropped from a variety of heights, was very popular; as were elephant's toothpaste, *Coke* and *Mentos*, vitamin C tablets with water or baking soda and vinegar in film canisters, as first choice experiments. The students' selection of these familiar, entertaining practical activities was enlightening as, when questioned why they had been chosen, the spotlight was on fun rather than on scientific enquiry. It appeared that the additional cognitive load required in developing their own research questions impaired the assessment process by making this, rather than the inquiry, the focus of student attention; this would tend to be consistent with the findings of a recent study into IBL and student achievement in England, (Jerrim et al. 2019), where the view was that the benefits accruing to students by allowing them to acquire their own knowledge were small.

Where inquiry was initiated through guided discovery, in this study, student outcomes were much more positive and effective engagement was more frequently observed. Examples of this were when the class first measured the effects of insulation on heat loss from beakers, or the design of wind turbine blades, in a semi-structured manner before being set free with the open ended task of 'finding the best design'. A similar pedagogy is of course the basis for student action cycles, (SACs), such as 'Greener Greens?'.

It would appear then, in summary, that the majority of young learners prefer to be told what to know, and that a careful, systematic and guided approach to the development of inquiry skills would be the pedagogical approach that best aligns with these students' perceived educational needs.

5.2.4 Curriculum content

After establishing, in the previous section, that the students from this study regarded curricula as immutable but transferable commodities, this section addresses how closely the pedagogies employed to deliver these met the needs of students, as they perceived matters, in answer to the first research question.

The introduction to this thesis mentioned concerns, raised during the review of junior cycle science, that there were too few opportunities for meaningful engagement with the curriculum, (NCCA, 2013). Meaningful engagement, as defined by Harlen and James, (section 2.4.5), involves deep understanding rather than superficial dabbling, described by Vygotsky as a vacuous and educationally fruitless acquisition of empty words that imitate concepts. Harlen and James proposed that deep learning is a progression, from that which has already been constructed by the learner, towards big ideas and skills that will impact on the learner's attitudes and values for both living and learning.

Several statements from the 'how I feel about school', (HIFAS), survey scrutinised student sentiments, to tease out evidence as to how pervasive their perception of meaningful learning opportunities, with regard to curriculum content, were as summarised below.

When the students' value of the curriculum was assessed through the statement, "In my opinion, most of what is taught in class is not worth learning", (HIFAS 27), a noticeable difference between those in first year, (n=111), and the rest of the school, (n=349), was noted, (section 4.2.8). Students new to junior cycle were much more lenient in their attitudes, with only six individuals in the year group strongly supporting the statement's stance; and a further twenty-eight agreeing somewhat. But for students who had progressed to second year, their impression of the value of their learning was significantly reduced, (r=1.484), and this decline was observed to continue in older class groups; even after they had had the opportunity to select options that potentially appealed more to their interests.

First year is largely regarded as a transitional, maturation period for students, as they are new to the school, and consequently the workload, intellectual demand and assessment processes encountered by them are much more forgiving than those they experience in later years. This may, in part, explain the difference in their reported impressions of content value. However, a major casual link between the student experience, or indeed a variety of other factors such as maturation or cognitive development, and the recorded decline in the perceived worth of curriculum content is almost impossible to definitively establish, as the potential determinants are so multi-various.

Linked to the statement just discussed was a further one that asked students to respond to, "Much of what I learn seems to be unrelated bits and pieces that I can't see the purpose of knowing", (HIFAS 40). Again there was a noticeable disparity between the responses from first year students and the rest of the school, with 9% of first year students in strong agreement compared to 23% by sixth year.

Compartmentalisation of learning was identified when students were questioned in focus groups about their whole school experience. Although one might imagine that students would appreciate the development of transversal skills, by the repetition and reinforcement of material and concepts in different departments, responses indicated that these links were not always obvious to them. Where overlap was spotted it was more frequently done so with disdain than appreciation; for example, negative comments such as, "why are we doing this? this is maths" and "why aren't we doing science like Bunsen burners and stuff cos this isn't science", were recorded when students were asked to plot graphs of data on themselves, such as height and arm span, that they had collected in class. Issues of confusion were also noted when alternate terminology was used in different subject areas covering the same material; such as in home economics where students refer to 'dairy' as a food group rather than 'fats', which is used in science.

Another general observation from the focus groups was that students frequently reported feeling overwhelmed by the content that they were expected to engage with during an average week; and the amount of homework set to consolidate this. They described feeling run from pillar to post, with curriculum engagement being more a matter of keeping up than active learning. Many of the comments echoed those from the Student Review of the Science Curriculum conducted by Murray and Reiss, (section 2.2.13), such as, "There are too many facts you have to learn off" and "Why do we have to learn stuff that we are never going to use in real life". It was noticeable though, that the overall impressions of the junior cycle course were more positive than for its predecessor, as will be discussed later. Finally, a rather mournful and despondent response from one senior cycle student summed up his assessment of his experience of leaving certificate biology as, "It's not like David Attenborough, is it!"

When viewed along with the results from the ways of learning questionnaires I and II, (WLQ1, WLQ2), student responses give a much clearer picture of how far from self-directed learners they considered themselves to be. The 2005 Murray and Reiss survey data, reporting on the effectiveness, enjoyment and frequency with which a selection of different teaching and learning styles were encountered almost exactly mirrored the results from this author's study. In both cases students considered taking notes from the teacher, doing experiments and having class discussions or debates to be the most effective learning approaches, while going on trips, looking at videos and conducting experiments to be most enjoyable. However, when this profile was compared to their reported everyday classroom experiences a significant mismatch between that which was desired and reality was revealed. Students reported that the most frequently employed teaching strategy was the chalk-and-talk of copying notes from the board and taking notes from the teacher, along with reading the textbook. It is worth note that verbal feedback revealed noticeable differences between the subjects; with some employing a much larger range of strategies than others.

When asked to clarify what they would regard as an ideal lesson for learning, students showed considerable variation in their responses. Whether these reflected a self-evaluated perception, personal experience, an idealised paradigm, or were merely the repetitions of their parents' wishes, is near impossible to establish. It is to be noted though, that although the WLQ1 and WLQ2 were intended to be completed anonymously, to reduce the likelihood of bias through offering what might be perceived to be the 'correct' responses by students, a number of individuals did attach their names. Of these exclusively, the most extreme suggestions, in terms of a wish for delivered instruction, regular testing and a removal of 'entertaining' lesson components, came from students who had joined the school from India, Pakistan and China, (n=18). These same sentiments were echoed by one of these students' parents at a parent-teacher meeting, where their wishes for numerical grades and percentages combined with teaching to pass the test were expressed; as well as their concerns about the less than concrete structure of junior cycle education for teaching "facts".

Wiliam's position, that effective learning, involving formative assessment, starts with the defining of clear learning intentions and sharing of success criteria was discussed in the literature review, (section 2.4.2), and, in line with this, over the last couple of years there has been a whole school focus on clarifying intent, with a directive that learning intentions be written on the board at the start of all classes. Nonetheless, the use of success criteria by teachers appears to be sporadic, according to those in the focus groups.

Without a structured linking together of the separate 'planks' of learning, there is a real risk that that is all they will remain - rather than the ordered rungs of a ladder. The King's Medway Oxford Formative Assessment Project, (KMOFAP), team, (Black *et al.*, 2006), suggested that students should be encouraged to take responsibility for their own learning; to be taught how to make the ladder if you will. To do this, they argued that in addition to being given a clear set of learning goals and instruction on how to achieve them, the process should be made more manageable by encouraging students to formulate an overview of the entire curriculum. It is the view of this author that keeping the flight-plan of the science specification to one's self with the view that students are unable to engage with the intricate structure, or demanding wording of learning outcomes, is a fallacy that underestimates the ability of many, and encourages teacher-reliance rather than the development of an independent learner.

Students, in this research, have frequently demonstrated their ability to locate their position within the whole program of study by self-identifying the learning outcomes from the strands and elements that match the work they are completing, as the illustration of a first year students' work below clearly shows.

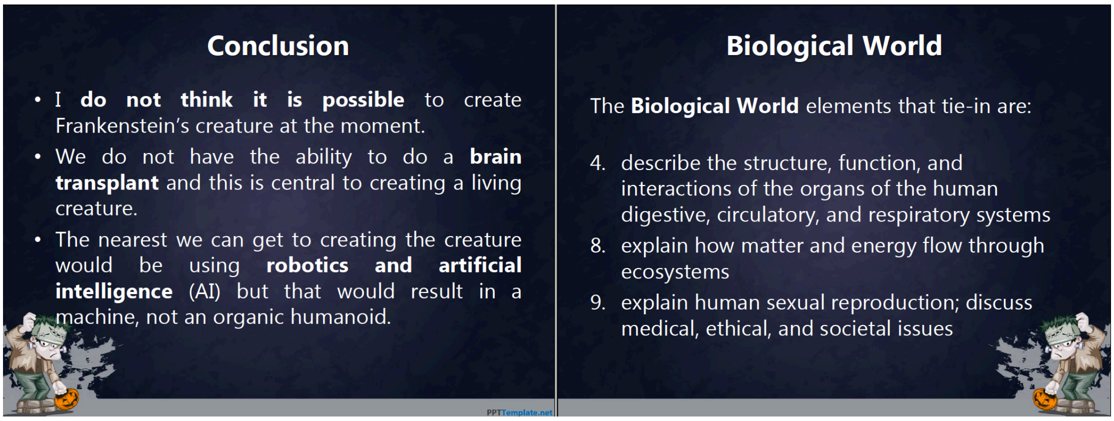
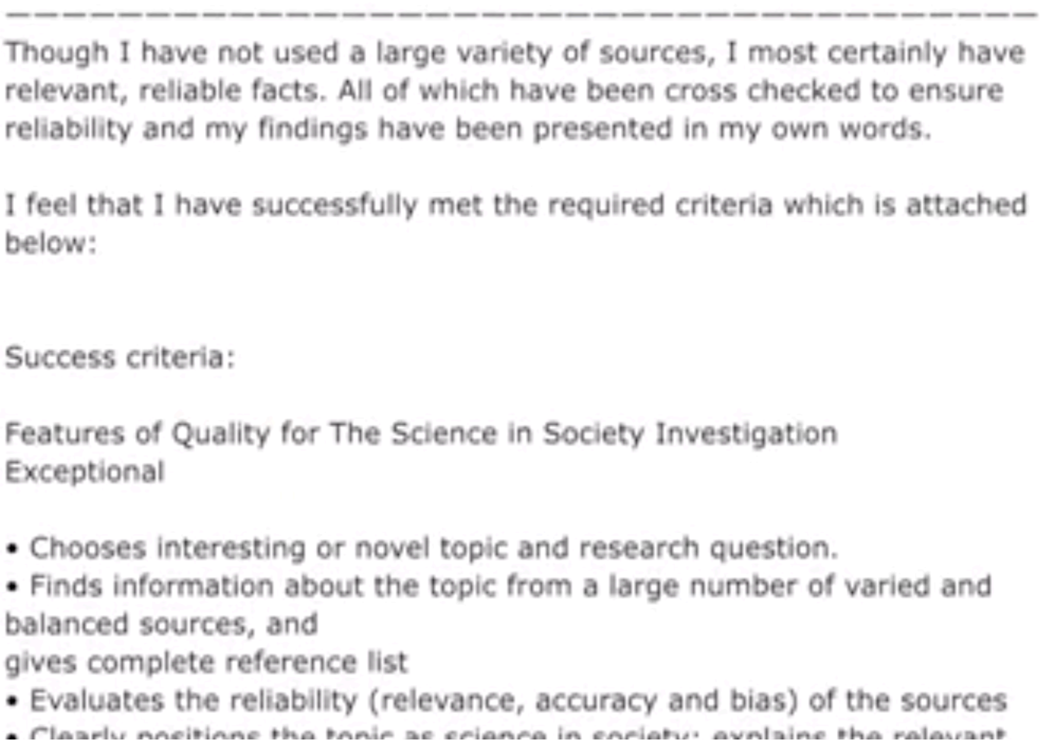


Figure 5.2.1 Two pages from the final presentation of a first year science student, tasked with using science to argue for the existence, or otherwise, of a Halloween monster, showing how she has related elements from the biological world strand of the junior cycle science specification to 'route-mark' her work.

More over, rather than identifying the learning outcomes as threshold criteria for success and worrying as to whether they had been met or not, unlike the Irish Science Teachers Association council members, (ISTA), students engaging with student action cycles, (SACs), when asked, described using them as useful route markers that indicated they were moving in the right direction on their journey.



Though I have not used a large variety of sources, I most certainly have relevant, reliable facts. All of which have been cross checked to ensure reliability and my findings have been presented in my own words.

I feel that I have successfully met the required criteria which is attached below:

Success criteria:

Features of Quality for The Science in Society Investigation
Exceptional

• Chooses interesting or novel topic and research question.
• Finds information about the topic from a large number of varied and balanced sources, and
gives complete reference list
• Evaluates the reliability (relevance, accuracy and bias) of the sources
• Clearly positions the topic as science in society; explains the relevant

Figure 5.2.2 A screenshot from an audio-visual presentation from a second year science student, who chose to investigate GM crops as an open-ended research task, showing how she has recognised the value of the features of quality for a science in society investigation to 'route-mark' her work.

Students and teacher working together in a learning partnership, Vygotsky's *obuchenie*, (section 2.5.3), is illustrated in the 'Greener Greens?' presentation that is attached to this document. Perhaps, as the changes in learning and teaching strategies that accompany the junior cycle reform embed themselves across all subjects, the student responses to statements such as the two just discussed will become more universally positive.

5.2.5 Social Constructivism

The perceived educational benefit of the co-construction of knowledge by students through social interaction has been discussed at length in the literature review, with evidence of its popularity as a pedagogy also being demonstrated in the previous chapter. What follows is a further clarification, through discussion, of the value that students, from this study, placed on classroom dialogue, achieved by amalgamating data from the 'how I feel about school', (HIFAS), survey, responses to the 'ways of learning-2' questionnaire and verbal feedback from focus group sessions.

Vygotsky's position that thought is completed in the word, (section 2.5.3), was investigated by the analysis of responses to four statements in particular on the HIFAS survey, that were designed to evaluate the importance that students placed on classroom conversation as a means of articulating thinking.

Students, (n=467), were asked to consider the conjunction of word-and-thought in, "The best classes are the ones where I can learn by talking rather than learn by listening.", (HIFAS 34), (section 4.2.5), and, in response, over 70% replied in the affirmative. However, a minor decline was noted in the proportion that declared that the statement was very much like them, marking the transition from junior to senior cycle, (30% to 25%). A similar positive response was seen for the statement, “I find it easier to understand new ideas if I talk them through with my friends.”, (HIFAS 4), where 75% of the school population were in agreement, and the distribution of responses in each category remained constant across all year groups.

When results from the statements, “I prefer classes where I can share and compare ideas with my friends.” (HIFAS 14), and “I don’t like to share ideas because others might not agree with me.”, (HIFAS 30), were analysed, a pattern comparable to the responses from the previous two statements emerged. Eighty percent of non-exam year students, (n=294), indicated that they preferred classes where they could share ideas and this dropped only slightly, to 68%, for individuals in third and sixth year, (n=164). For the second statement, just over half of the students polled, (n=462), indicated that they appreciated opportunities to share ideas, whether or not others agreed with them.

The ways of learning-2 questionnaire, and focus group sessions, gave deeper insight into the thinking behind the students’ responses to HIFAS. For example, Mercer’s argument, (section 2.5.3), which is a reiteration of Vygotsky’s position, that a primary role of education should be to enable students in the use of language as a tool for collective intellectual activity through the development of intermental development zones, (IDZ) was substantiated by student comments such as, “we are able to help each other and go through problems we might have had”, “talking through our work with my group can let me get more information off them and I can get to see their opinions”, and “because it gets things done and we are communicating”.

The concept of the value of an IDZ is very clearly visible in the following dialogue recorded in a focus group session:

> 'It's much easier to talk your ideas over like cos then you have to think about what you are saying and such and it makes you think more….' [interrupted]

> '…. Yeh, but like sometimes you don't agree and that's frustrating because and if say, if like you have a good idea, and you say it, and someone's not liking it then….' [interrupted]

> '…. but then you talk about it don't you, that's the **whole** point, you talk about it and you sort it out' [whole was emphasised by the student]

'Student-speak' may be thought of as a co-constructed cant that, by definition, is at an appropriate and accessible level for those communicating. The value of group work in facilitating its use was highlighted by a noticeable proportion of respondents in comments such as, "because I cant understand the work when the teacher is explaining it", "if you talk it with your friends it is easier to understand what you are doing" and "because it makes it explained better to understand becaus theres more opinions". (spelling from originals)

New ideas, and different perspectives, were identified by others who wrote, "You get other peoples inputs and opinions you might not have thought of", "so that I can compare my work to other people" and "I like to talk in a group as I hear other peoples views and have more fun.” These comments might well have been used by Sivan, (section 2.2.3), to elaborate on his discussion of motivated group behaviour, where he described it as “a socially negotiated process that results in an observable manifestation of interest and cognitive and affective engagement”, (1986 p.210).

Productivity and enjoyment also featured prominently in feedback from students in, “it gets my mind more use”, “it makes me more confident and benefits my work as I get constructive criticism", “as sometimes the teacher is busy and a friend can explain something to me that I don’t understand” and, “when you’re working with a friend it makes school more enjoyable.”

By and large, as can be seen from the data, the student population responded very positively when asked about learning through talking and group work. However, the value of the mixed-methods approach employed in this research became abundantly clear when looking at the written responses from a number of students on the ways of learning-2, (WLQ2), questionnaire, who expressed opinions that were never vocalised in the focus group sessions; for reasons that are self-explanatory. These go some way to explain the negative responses to the respective HIFAS statements.

Confidence, or rather the lack of it, appeared most frequently in feedback from students who stated that they did not like group work. The main themes of the negative responses related to self-image can be summed up in the following selection of quotes: “I am very shy”, “I sometimes get nervous”, “I try to avoid talking altogether, all the time”, “I prefer to do my own thing its safer” and, “I am really bad at it”.

A reluctance to work with others also arose in several responses such as, “because people don’t think like me and it makes me mad”, “no because I like to use my own ideas” and:

> I find it to be of little benefit by talking about my work with my peers and rather discuss with the teacher who is more engaged & interested.

One student identified his ideal learning lesson routine as one where,

> I sit at the back of the room with no one sitting at the tables beside me and work in complete silence, with the teacher never asking me any questions.

Task completion appeared to be the main priority for some individuals who wrote comments including, “it can feel awkward or unnecessary for shorter work”, “I much prefer to work on my own as there are no distractions.” and, “sometimes I may find information I didn’t know but most of the time I prefer to work on my own”.

Some students appeared to entirely miss the intended purpose of group work as exemplified in answers such as, “because they could copy your answer and I could have got it wrong and then we will all get in trouble for copying” and “If we do groups then we can be cheating and the teacher wont know who it is”.

But to summarise, the majority of responses were highly supportive of the use of group work as a tool for learning with many students clearly articulating the educational benefit they perceived in the pedagogy.

5.2.6 Flow

The work of Csíkszentmihályi, with respect to flow theory, was discussed in section 2.2.9 of the literature review and also examined through the results from the 'how I feel about school', (HIFAS), survey.

It could be argued that an indicator of a perfect match between pedagogy and the educational needs of the student would be when the enjoyment experienced through working through challenges, that are appropriately matched to the skill-set and experience of the individual, is such that the passage of time goes unnoticed. Students working in the 'flow channel', as Csíkszentmihályi contented, would be highly intrinsically motivated and working single-mindedly towards goal completion.

In this study, students, (n=447), from all year groups, where presented with HIFAS statement 46, (section 4.2.4), "When I am working I don't notice time passing.", and the responses exhibited a remarkable similarity, in that nearly three quarters of them, (n=326), were in agreement. Similarly, 60% of those asked whether they enjoyed difficult and challenging problems responded in the affirmative, (HIFAS 26, (n=463), and 38, (n=450).

In focus group sessions many of the aspects associated with flow, such as the ability to become absorbed in a task, a sense of control, total concentration and a loss of a sense of time were mentioned. That flow activities are tasks that can be completed, with clear goals and immediate feedback, however, was not specified.

In illustration, a few of the students' reflections are included. Enjoyment appeared in, "The best is when it's, [the work], made fun for you to do, like, and it's thrilling", while the match of task demand to skill-set was voiced in, "If it's like a challenge then it's fun when you win at it and get it right". The loss of a sense of time was most frequently mentioned, for example: "When you are doing work on what you like you don't notice the time", "When me and [student] can do work on our project then I don't notice the class going", as well as, "Woodwork and PE is the best cos you don't feel like it's work and the time just goes." One first year student remarked,

> I love it when it's like, was that the bell, and you don't think you've been in for a whole class already

while a second year stated,

> I like it when we done the stuff on our food and where it all comes from cos when we done that we could do what we thought of and when we are doing it the time just flew

Even though one hundred and nine of the student's in exam years, (n=157), had identified with not noticing the passage of time when they were absorbed in a task, when it came to elaborating on this in focus group sessions, no comments were forthcoming. It may well be that the examination preparation that these students were undertaking, though it may well have been very repetitive, and certainly highly structured, at times engendered feelings of flow.

5.2.7 Assessment and feedback

The use of feedback, was discussed at length in the literature review, and student perceptions assessed through both focus group sessions and also by responses to two particular statements on the 'how I feel about school', (HIFAS), survey, (section 4.2.6).

The first HIFAS statement, (32), asked for an opinion as to whether tests are an essential tool in the process by which teachers gauge the performance of their students. Slightly over half of those asked, (53%, n=464), concurred, but when their reasoning was examined further, in several focus group sessions, what emerged was, that for some, the wording of the statement had affected their response. In reading, "I think the only way a teacher can know how I am doing is by giving me tests.", all agreed that testing was an effective summative tool but many were eager to point out that informal discussions, or debates, could also provide valuable information. The difference between 'understanding' and 'remembering' was highlighted with some of the students commenting that the written tests too often focussed purely on recall. Noticeably, the use of assessment by written tests was more favoured by female and Asian students in the groups. The following is a transcript of a sample of dialogue:

> Of course we need tests… [interrupted]
>
> … No you don't. If the teachers stay engaged with us students and don't do the reading from the book at the top of the class then they'll know where you're at
>
> But I like tests cos then you can let your parents know you've done good
>
> Yes but they don't test everything do they. You might just understand it but not remember the words that get you marks

Although students recognised the value of classroom dialogue in assessment, and certainly regarded informative feedback as essential, none of them went as far as the students in Cowie's study, (2005), who had claimed that their thinking could not have been assessed unless the teacher had come round and spoken to them during class.

Several discussions examined the purpose for testing, that is to say, its summative or formative role. One exasperated student expressed his wish for the later when he commented:

> We want to be having it while we're doing it. Not at the end. Why do we always get it at the end?

There was some evidence of subject specific preferences for particular assessment strategies, and multiple references were made to the classroom based assessments, (CBAs), that are a feature of the junior cycle reform. Skills testing, not unsurprisingly, featured heavily in discussions around mathematics where comments such as, "You just need to be able to use the formulas", "It's easier cos you see the question and like there's only one way to do it" and, "You don't need to remember it, you just need to learn how you should be doing it", were voiced. Memory and skills both appeared in discussions of English, where students mentioned the poems and plays that they had to 'learn off' and compared this to the creative process of essay writing. In science, the predominant expression from students in the control group was that factual recall was most important. The sample group were less unilateral in their opinion and the comments, "Yes there's science you need to know, like the names of things, but you still have to be thinking it" and "A lot of it is down to using your brain and common sense", exemplify this.

After investigating perceptions around the purpose of testing, the focus groups were asked to elaborate on HIFAS statement 6, "I prefer comments that show me how to improve over grades."; to which 83% of students polled, (n=463), had responded to in the affirmative. This statement was included to attempt to establish whether the results of Butler's research into the contrasting effects of numerical grades and comments was mirrored by the students from this study, (section 2.2.6).

Students clearly differentiated between the value of a grade for recognition, or reward from peers or parents, and informed comment that could move learning forward. As one student articulated, "It's cool to get top marks because then they can be proud of what you've done". In this study it was noted that on several occasions students who had been given comment only feedback on their work requested that they be permitted to work further on it and resubmit. On the other hand, students who were given less than optimal scores on recall tests, showed no interest in retrying, and papers were left in the classroom on their departure.

Students were also asked about what level of support constituted the most effective written feedback; that is to say how they would wish work to be annotated. The extent of correction appeared prominently in comments, particularly for essay style responses for coursework, as students stated that too much red ink was demotivating and removed control of the work from themselves; very much echoing the recommendations of the King's Medway Oxford Formative Assessment Project, (KMOFAP), team, (section 2.4.7), not to use red ink and to write legibly and with meaning and appropriate language such that the intention could be understood. The following are representative of views expressed in focus group sessions:

> I like when you mark it in pencil cos then I can rub it out easier if I want to, and it doesn't spoil my work.

> I hate it when you do stuff and it comes back all scribbled over everywhere or when it's like your ideas are no good because you did it different.

> It's good when you get, when I get smileys like *well written* or stuff like that as well instead of always negative comments. And not too many. If it's all *do this again* then it's like why bother.

Very much in accord with the processes implemented by the KMOFAP team, the student feedback from this study can be read as asking teachers to focus on what has been achieved, with not too many suggestions as to what to work on. This brings to mind the work of Torrance, who noted that students who receive critical comments, even when given advice on how to improve, are unlikely to make productive use of the feedback, especially if they disagree with the remarks that were made.

Another recommendation from the KMOFAP team that students commented on was the use of concrete examples and success criteria. Indeed, as has already been illustrated in the examples of student work, (section 5.2.4), success criteria were often observed during this study as being used as guidelines by students to affirm the quality of their own work. Exemplars on the National Council for Curriculum and Assessment's, (NCCA), website curriculumonline.ie and accompanying *features of quality* were mentioned as being particularly valuable in 'helping us see what we have to do'.

In summary then, positive affirmation, suggestions for improvements and respect for the work that had been handed in, with regard to the annotations made on it, were regarded as characteristics of good feedback as far as the students in this study were concerned.

5.2.8 The junior cycle science examination

A further investigation, performed in an attempt to answer the first research question, "How closely do specific pedagogical approaches align with students' perceived educational needs and attitudes towards science?", was through analysis of focus group sessions with fifth year biology, chemistry and physics students.

The 2019-2020 cohort of fifth year students was remarkable in that some had progressed directly from their junior cycle studies, while others had completed the junior certificate course and a transition year. This combination of experience allowed for a review of the junior certificate and cycle science terminal examination through the lenses of experience of both curriculum and specification. All of the conversations discussed below are transcriptions of excerpts of recordings of private student sessions, which lasted approximately twenty minutes, and during which there was no teacher present. Spelling reflects the words that were used by the students.

The papers considered by the groups were the 2019 junior cycle science examination, (https://www.examinations.ie/tmp/1580935685_9858031.pdf), and, (https://www.examinations.ie/tmp/1580984774_296854.pdf), the 2018 junior certificate higher level science paper.

The first conversation was between chemistry students. Students B and C had followed the junior cycle course.

Student A

'Are these, these like this, you can use your like, [long pause], imagination and then junior cert is more like memory based if you get me, does that make sense?'

Student B

'What?'

Student A

'Yeh, you could have went through the junior cycle with common knowledge'

Student C

'Yeh'

Student A

'If I ever got that wrong, like this, if I ever got this wrong which you can't'

Student D

'They give you too many hints in the junior cycle to be honest. In junior cycle they just give you too many hints'

Student A

'They're literally spoon-feeding it to you'

Student C

'Yeah, it was good'

Student A

'That's so unfair'

Student B

'Like if you read the question the answers are in the question'

Student E

'I could do this like, I could do this… oh my god like, I really think there's not enough there'

Student B

> 'No like if you read the question like, the answers, they give you the answers'

With comments that were common to all discussions, the students highlighted two major concerns that they had with the junior cycle examination; namely that they felt it lacked academic rigour and that it did not test the knowledge of the candidates sufficiently. Students who had completed the junior certificate course perceived that they had been unfairly treated with an examination that they regarded as considerably more demanding than its replacement.

A similar sized group of fifth year biology students were given the same papers and the discussion they had raised identical concerns. The group went as far as to suggest that the State Examinations Commission should bring back the higher and ordinary level paper distinctions. That the junior cycle should be a preparation for leaving certificate studies was also mentioned. Students F and G had followed the junior certificate course.

Student F

> 'What was the purpose of making this common level?'

Student G

> 'Yeh, it is common level, I did higher level'

Student H

> 'Wait, there was, junior cert was lower and..'

Student G

> 'Yeh, we had higher and lower'

Student I

'Oh they should bring that back'

Student F

'Question 1, We have to know about like the joints and everything as well, we had to know about all the archeries this is literally kinda like fifth year'

Student J

'You'd actually learn more if you did junior cert, yeah'

Student F

'Look, we had to know the digestive system a lot … [pause] … and about food'

Student G

'Like, I, I, like looking at your test, it looks too easy'

Student I

'I would be angry too if I did the junior cert'

Student F

'This is a joke'

When the same papers were given to a second group of leaving certificate biology students the following interaction was recorded. Once again the apparent lack of content was regarded as an issue, even to the extent that it was felt it might be possible to pass the examination without having studied the subject at all. Very clearly, the perceived educational needs of the students extend to assessment and they reported, loudly and clearly, that it was their opinion that the junior cycle examination was not fit for purpose. In this discussion students L, M and O had completed the junior certificate course.

Student K

'I'm just looking at the level of difficulty, it's just you actually mean more'

Student L

‘Oh we did this experiment, you, you used em, you used hydrogen peroxide and er marga, manganese’

Student M

‘Oh and then the gasses, yeh?’

Student L

‘You make the oxygen and then you put it into like a container and you put er, you put a light, a match, and lit and then you put it in and it’ll just go out and then carbon dioxide it would relight, and then hydrogen it will make a pop noise’

Student K

‘It seems like you actually have to learn stuff for, for actually junior cert’

Student M

‘Yeh, no, that’s what I’m saying it’s more like definitions and memory where that can be just general knowledge’

Student K

‘Yeh, common knowledge’

Student N

‘Look this is like atomic number like literally and isotope, like we didn’t know them’

Student O

‘Like you could have not done chemistry, like not done science for the whole three years and still would have done well’

Student M

‘In this one they just give you too many hints’

Student O

‘They give you, no no no no that’s not ok, why do they give you the words to write here? We never got like this’

Student M

> 'I know'

The final group to be mentioned in this review of the 2018 junior certificate and 2019 junior cycle papers was an alternate fifth year class of chemistry students. In their discussions they reiterated the points of the previous groups but also attempted to identify the purpose behind the overall structure of the junior cycle science course. The lengthy discussion, of which the following is only a small fragment, repeatedly focussed on the difference between thinking and remembering, (or 'regurgitating' as they referred to it), as two important aspects; this very much brings into focus the ideas that information without the ability to apply it to real life situations is of little value. Creativity and personal opinions were also two features that appeared in their consideration as can be seen below. What was most significant was the role that students assigned to junior cycle based on the assessment, as opposed to junior certificate. Serious concerns were raised as to whether it, or the course, adequately prepared students for the high stakes leaving certificate examinations, that they identified as their gateway into a third level course of their choice. Students R, S and V had completed the junior certificate course.

Student P

> 'This one is like a memory test'

Student Q

> 'Biology is kinda memory, but then like then, then it goes into chemistry also kind of the same as the kind of thing we're doing in, right now'

Student R

'Yeh, but this one its just like they have like the answers like there... they basically have to fill in boxes in that question'

Student Q

'No but his point is like this isn't memory, like some of the things like the answers are given to you but you had to think of like, you had to… it might have been easy to like figure out but like you had to think of it'

Student S

'So you might need to use your brain'

Student P

'Yeh you had to use your brain'

Student T

'It's like knowledge you have to use your brain not like, but with that like you just have to remember it and then like regurgitate it'

Student S

'So you're basically saying that like honestly I prefer studying that one because I don't like stating my own opinions'

Student Q

'Yeh, because in this like if I say my own opinion it would be different'

Student S

'Ah like this like, I get what you mean it's like more opinion, so like there's your own answer like after reading that it's like do you agree or disagree with the use of animals such as mice in science research? Explain your answer. So like you can't, you technically can't be right or wrong'

Student U

'I would rather junior cert because I feel like this, you would learn eventually like more, you would learn more information, and it would help you in sixth year and fifth year because right now we are just redoing the junior cert in a way'

Student R

'We had more stress as well'

Student S

'I get the like, what they're trying to do, but…'

Student R

'They're trying to make it easier and more creative'

Student S

'But like I get the point of like trying to make it like, but now it's like'

Student V

'No, because if its junior cert to the junior cycle they're going to be like oh this is easy, we don't need to study for this, but for me I was studying really hard for junior cert. That's what I see'

Student S

'Wait, look, this page is harder than your full …'

Student V

'Yours isn't hard though. This is child's work, man. Which appliance listed in the table uses the most electrical energy? It tells you the an.., like literally it tells you the answer'

Student R

'I'm so annoyed, I'm so annoyed, I'm so annoyed'

Student V

'It's not even a hint it's just blatant. The answer. The answer is there.'

Student S

'If I didn't study for that, If I came in to do this like I would have passed it easy, like its, like most of this is common sense.'

Student R

'Two renewable sources of energy, tick the box'

Student S

> 'I could literally answer the whole thing'

To sum up, very clear differences in the style and demand of the two courses were apparent to the students through their brief review of the two examination papers. The knowledge and understanding aspect of education came up in all discussions. The imminence of their leaving certificate examination, where the points gained are regarded as the most important achievement, (in line with the tenets of diploma disease), was considered with a view to how much content knowledge had been acquired by the students who completed junior cycle in comparison to those who had studied the junior certificate curriculum. Student U's comment highlights the concern of a number of junior cycle students that they had not acquired a sufficiently broad base of content knowledge for the courses they were currently undertaking.

5.2.9 Attitudes towards science and the student action cycles

Students attitudes towards science were also assessed through the analysis of data collected from selected statements from the 2015 and 2019 Trends in International Mathematics and Science Study, (TIMSS), questionnaires, as well as exit ticket responses, (section 4.3), and focus group sessions.

In 2016, the specification for junior cycle science, (SJCS), was enacted and replaced the junior certificate science syllabus, (JCSS). With the obvious potential for this to influence the interpretation of data collected from this study, student perceptions of the subject from 2015 and 2018 were first compared using comparable TIMSS statements, as discussed in the next section, prior to analysis of pre and post intervention data using student action cycles.

5.2.9.1 Changes in attitude towards science

When the results from this study for the proportion of second year students, (n=148), following the junior certificate science syllabus, (JCSS), that responded in the affirmative to the statement "I enjoy learning science", (Figure 4.4.2), were compared with those established by TIMSS in 2015, (Figure 4.4.1), they were found to very closely approximated the Irish average. The implication from this is that as the data collected for that year in this study was consistent with the larger Irish student population, the school may be also regarded as representative of a typical Irish secondary school.

The process was repeated in 2018, again with second year students, (n=158), two years after the introduction of the specification for junior cycle science, (SJCS). This time the number of girls who expressed an enjoyment for the subject had dramatically increased, from 70% to 89%, while the attitude of the boys remained unchanged, but positive, at 72%, (Figure 4.4.4).

In 2015, 44% of boys and 52% of girls agreed with the statement that 'Science is not one of my strengths', (Figure 4.4.9), and this distribution was almost unchanged when the similar cohort was sampled in 2018; rising only slightly to 45% for the boys and

57% for the girls, (Figure 4.4.12). The proportion of boys who agreed a lot with this statement rose by 9% for the second sample while the proportion of girls, holding the same position dropped, by 14% to a negligible 4% of the female population.

Related to the previous statement is ‘Science is harder for me than other subjects’. For this there were very noticeable gender and temporal differences in the results from the questionnaires. In 2015, 43% of boys and 40% of girls agreed with this statement, (Figure 4.4.15), but by 2018, this had almost halved to 24% for boys and conspicuously fallen to 5% for girls, (Figure 4.4.18). This increase in confidence was also noticeable in the changes in the proportions of students who strongly agreed with the statement; 20% to 12% for boys and 15% to 5% for girls.

While it is impossible to rule out the effect that sampling different cohorts has on these results, the major substantive change in student experience was the rollout of junior cycle. This change was implemented by the National Council for Curriculum and Assessment, (NCCA), with the expressed intent of increasing the relevance and connection between the subject and students’ lives through potentially increasing the possibility for enjoyable and engaging learning activities based on the science specification. A conclusion that might be drawn from these data, showing a reported increase in enjoyment of the subject in 2018 over the preceding cohort, is that of successful implementation of the junior cycle specification.

Task enjoyment, according to Csíkszentmihályi’s flow theory, (section 2.2.9), is inextricably linked to the balance between the complexity of a challenge and the skill set of the individual. He proposed that work that is challenging, but achievable with effort, with clear goals and immediate feedback, would promote intrinsic motivation and create flow. The use of success criteria and features of quality, as outlined in the specification, most definitively fulfil the parameters of clear goals and also prescribe a means of authentic feedback. The reported increase in enjoyment of the subject by the 2018 cohort, over their fellow students from 2015, marks a concomitant increase in feelings of success, as shown by the rise in those who reported it not harder than other subjects. Success and achievement, as markers for skill and challenge, could be construed as setting a position for the student in the flow channel; that separates anxiety from boredom, (Figure 2.3). The open-ended nature of the learning outcomes from the specification may be facilitating the setting of tasks that are not too easy, or too hard, and hence maintaining the experience in flow, rather than in boredom or anxiety.

That the proportion of students who regarded science as one of their strengths remained relatively static is of interest in that it appears to be independent of the course being undertaken. When students were asked about this in focus group sessions, responses largely referred to an intrinsic ability that the individuals regarded themselves as possessing; with little or no reference to the extrinsic nature of the curricula being studied.

5.2.9.2 Student action cycle pre and post intervention results

In attempting to resolve whether the use of student action cycles impact on attitudes towards science the responses to a selection of Trends in International Mathematics and Science Study, (TIMSS), questions, completed by second year students in 2015 and 2018, were analysed before and after their engagement with student action cycles, (SACs).

The comparison of pre and post implementation data from 2015 indicated that the cohort, (n=51), were slightly more positive about their science studies after completing SACs, (Figure 4.4.5), than beforehand, (Figure 4.4.3). Sixty-two percent of students agreed “a lot” or “a little” to “I enjoy learning science” prior to the use of SACs and this rose to 71% afterwards; although this change in attitude was found to be relatively weak (r=0.443).

When the same analysis was performed on the 2018 cohort, (n=47), (Figures 4.4.6 and 4.4.7), the pre and post intervention results were remarkably similar, (p=0.317), indicating no real difference in enjoyment of the subject with the different approach.

The comments from focus groups for the two cohorts provided some insight into the trends in data. Students following the junior certificate science syllabus, (JCSS), remarked on the difference in the approach to learning compared to their normal engagement, but junior cycle students, following the specification, (SJCS), focussed more on content than on delivery. The active learning strategies embedded within the specification in the unifying strand of nature of science, designed to make the classroom ‘a dynamic and interactive space, in which students are active participants in their development’, (NCCA, 2015, p.11), appear to have resulted in a pedagogical approach that is not too dissimilar from the SACs themselves. The similarity was such that students did not identify the work with SACs as being any different from normal classroom work.

Confidence in science was assessed, as mentioned in the previous section, by analysis of responses to ‘Science is not one of my strengths’, and ‘Science is harder for me than other subjects’ pre and post intervention for both junior certificate and junior cycle students.

The comparison of results from 2015 showed that a greater proportion of students felt that science was one of their strengths after completing SACs than beforehand (Figure 4.4.10 and Figure 4.4.11); with numbers rising from 46% to 55%, although this change in attitude was found to be relatively weak (r=0.370). When same question was asked of junior cycle students in 2018, no evidence of an effect of SACs was noted, (p=0.180), (Figures 4.4.13 and 4.4.14). Of note is that the change in the proportions of student responses in each category from the 2015 data was not supported by the more general findings for the cohort as a whole.

Possible effects of SACs on the accessibility of the junior certificate syllabus and junior cycle specification to students was assessed through the statement, “Science is harder for me than any other subject”. In a reversal of the pattern previously observed, pre and post intervention results from 2015, (Figures 4.4.16 and 4.4.17), showed only minor differences that cannot be attributed to the use of student action cycles, (p=0.317) whereas the results for 2018 revealed a relatively weak, (r=0.292), but positive increase in the percentage of students disagreeing with the statement. This is at odds with the rest of the pre and post data and no specific explanation for this divergence was identified other than the contention that junior cycle science provides a more accessible approach to learning than its predecessor.

An asymmetry between the curricula was supported by feedback from fifth year biology and chemistry students who were asked to conduct a comparison of junior cycle and junior certificate state examination papers. The focus groups provided an invaluable, once-off opportunity for comparisons, as they were comprised of students who had progressed directly from junior cycle and others who had taken the transition year option. The result of this was that the groups contained a mix of individuals with experience of one or the other course.

Students that had followed the junior certificate science syllabus, (JCSS), were dismissive of the junior cycle examination and questioned whether it prepared those who had studied it for leaving certificate courses. Those who had followed the specification for junior cycle science, (SJCS), were much less vocal than their peers when considering the content of junior certificate examinations. It was the universally expressed opinion that the junior cycle examination was much less demanding than the examination it replaced. As a caveat, it must be noted that the junior cycle examination is a common level paper whereas the junior certificate examination was set at higher and ordinary level.

The last two statements considered in this section are “I think learning science will help me in my daily life”, and “I would like a job that involves using science”. Very minor differences were noted in the pre and post intervention data but in neither 2015 nor 218 where these such that they could be ascribed to the use of student action cycles.

Analysis of data from entry tickets presented to second year students six times over the course of their junior cycle studies, three times prior to SACs and standard units of work but after the learning intentions had been explained, showed that students were slightly more positive, (r=0.122) about the prospect of engaging with SACs than otherwise; sixty-eight percent with standard instruction rising to seventy-five percent with SACs, (Figure 4.4.34). These numbers are not significantly different from those obtained from TIMSS statement “I enjoy learning science” though promising in that the majority of students appeared to be motivated in their science studies.

5.2.9.3 Attitudes towards science – a conclusion

It can be concluded that other than with regard to the motivation to engage, the use of student action cycles has little to no impact on attitudes towards science since the introduction of the specification for junior cycle science, (SJCS). For students engaged with the junior certificate science syllabus, (JCSS), the student action cycle approach was found to be slightly more attractive than *traditional* units of work. It would seem that the predominant positive influence on student perceptions towards the subject has been the implementation of the specification. The learning activities associated with the course itself appear, from the findings of this limited research, to be more appealing to students than its predecessor.

5.3 Collaboration

In answer to the second research question, 'Do student action cycles impact on student collaboration?", the limited data from the collaboration survey, (section 4.6), would suggest that they do, and that the impact involved positive engagement; though further and more extensive data collection with a larger group size would be required to be emphatic on this position. The small sample, (n=45), that engaged with the student action cycles, (SACs), did however show a move toward greater collaboration, (r=0.242), when compared to their work on more *traditional* units of learning. There is however plentiful data from this research that indicates that the majority of students relished the opportunity to engage in cooperative and collaborative work and valued these as highly effective learning strategies. It should be noted that the framework for junior cycle involves the key skill of 'working with others' and that collaborative and cooperative group work was noted as a much more frequent aspect of all junior cycle classes, when compared to junior certificate studies.

5.3.1 Opinions on group work

Student opinions, with regard to group work, were collected through responses to a number of instruments, and also through focus group discussions. These included the 'how I feel about school' survey, (HIFAS), (section 4.2), the 'ways of learning questionnaires' I and II, (WLQ1, WLQ2), (section 4.3), the collaboration survey, (section4.6), and reflections on learning, (section 4.4.6).

HIFAS offers students the opportunity to respond to four specific statements about how they value active interaction with their peers. As mentioned in the literature review, (section2.5.3), and section 4.2.5, there is a contention that dialogue between learners in the classroom helps to develop understanding in the participants, in support of Vygotsky's position that thought is completed in the word. It is argued that the very process of articulating ideas assists in the development of meaning in a way that is much more than just thinking out loud. Vygotsky referred to this as 'verbal thinking' and argued that there was a unity in the term that was quite distinct from the two separate processes from which it is combined; much in the way that water is very different from the hydrogen and oxygen that comprise it.

Three-quarters of students asked, (n=471), were emphatic that it was easier for them to understand new ideas if they were permitted to talk them through with their friends, (HIFAS 4, Figure 4.2.29). Comments from the 'reflections on learning survey' reinforced this, as there was frequent mention of the support that discussions with peers provided in the learning process. This was not a universal position however and

26% of the participants in HIFAS 4, and 19% of those who completed WLQ2, (n=120), were in disagreement. These proportions were not matched by the frequency of negative comments in reflections though, where there were very few about group-work. Some reflections referred to others in the class not respecting the position or suggestions from students, but apart from this, no greater clarity was provided by them. However, in HIFAS 30, just under half of the students, (n=462), agreed that they did not like to share ideas with their friends because their friends might not agree with them. This is a clear example of a lack of confidence in one's personal perspective, or resilience, and certainly some of the participants who had negative views towards group work would be less socially adept than their peers. A few reflection responses referenced note taking, bookwork, and testing, and it is possible that collaboration was seen, by the students who mentioned these, as the antithesis of diploma disease.

This still leaves a mismatch between classroom practice and student opinions on effective learning environments, as students, (n=114), reported on the WLQ2 survey that they spent approximately two-thirds of their time either being talked at or working quietly on their own, (Figure 4.3.1). Compare this to roughly three-quarters of students who responded in the affirmative to HIFAS statement 14, which asked them specifically as to whether they preferred classes where they could share and compare ideas with their friends.

The results from the investigation into distraction indicated that one-quarter of the students polled considered noise as a major distractant. The conversation of other groups would of course fit into this category, and this might provide some insight into why a similar proportion of students, in answer to HIFAS 14, stated they preferred not to work with their friends.

5.4 Cognitive development and student action cycles

Data in response to the final research question, 'Do student action cycles impact on cognitive development?', was presented in section 4.7. This involved analysis using the "*Volume and heaviness*" science reasoning task, (Wylam & Shayer, 1978), prior to engagement with student action cycles, (SACs), and with "*The pendulum*" after the SACs had been completed. Minor gains, (r=0.06), were noted but it is not feasible to assume that these were solely the result of the student action cycles conducted, as neither of these specifically addressed material relevant to the second task, namely the manipulation of multiple variables. Relationships between levels of cognitive ability established by "*Volume and heaviness*" and both the Drumcondra Reasoning Tests and CAT-4, (cognitive ability test), were observed, and this also extended to performances in the junior certificate English, mathematics and science examinations.

5.4.1 The two science reasoning tasks (SRTs)

The science reasoning tasks, (SRTs), used in this study were developed by the CSMS team, (Concepts in Secondary Mathematics and Science), in 1978 and are criterion referenced to allow for the identification of students' Piagetian sub-stages. They are largely based on material from 'The Growth of Logical Thinking', (Inhelder & Piaget, 1958), and are intended for use with students between the ages of nine and sixteen. Of the seven tests devised, only two, "*Volume and heaviness*", and "*The pendulum*", (Appendix II), were employed.

"*Volume and heaviness*" starts with the water pouring tasks that are detailed in the first chapter of 'The Child's Conception of Number', (Piaget, 1952), and then moves on to the domain of conservation, an early concrete operational concept, (2A), with a question on popped and un-popped maize. Late concrete operations, (2B), are next assessed with questions on density and water displacement using a plasticine block, the shape of which is modified in a number of ways. Early formal operations, (3A), questions compare the density of the lump of plasticine to a brass block, and water to washing-up liquid, and then move on to ask how Archimedes might have solved the problem of the king's crown. The questions on conservation and density are based on material from 'The Child's Construction of Quantities', (Piaget & Inhelder, 1974).

"*The pendulum*" is based in its entirety on chapter 4 of 'The Growth of Logical Thinking' and looks at the manipulation and control of variables and deductive reasoning. As such it is designed to assess late concrete, (2B), and early formal operational thinking, (3A). In this task students investigate how the length of string, strength of push and mass of pendulum affect the period of the swing.

5.4.2 An historical comparison of cognitive abilities

What is significant in this study is the difference between the means of the data collected in 1974/75, (Figure 2.7), by the Concepts in Secondary Mathematics and Science, (CSMS), team, and those collected by the author in the interval 2014 to 2018, (Figure 4.7.1). The CSMS data shows a peak in distribution at the Piagetian mature concrete operational sub-stage, (2B*), which had regressed to middle concrete operational, (2A/2B), shown in the author's data; over the forty years since the first study. This difference could be explained away as experimental error based on the relatively small sample size of the author, (n=499), compared to that of the original study, (n=14,000), or on a myriad of other factors, if it were not for the fact that they exactly mirror the results from research conducted between 1975 and 2003, (Shayer, Ginsburg & Coe, 2007), in sixty-nine schools in England, (n=10,023). Shayer, Ginsberg and Coe describe the regression they recorded as 'a large anti-Flynn effect, (p25); referring to evidence of a linear increase in the intelligence quotient, (IQ), of the population which requires IQ test to re-standardize, such that a score of 100 represents the median performance of the standardization sample, (the Flynn effect, (Flynn, 1987)). They go on to question the assumption that children leaving primary school are becoming more intelligent and competent. The regression in Piagetian sub-stage, and concomitant increase in performance on tests of crystallized intelligence, namely learned or culturally established knowledge and skills, and fluid intelligence, here-and-now thinking, could indicate that test-taking ability or teaching-to-the-test rather than cognitive ability is what is improving. This would be very much in line with the proposals of diploma disease.

5.4.3 Accounting for the decline in performance on SRTs

There is clear evidence that student performance on the science reasoning tasks, (SRTs), produced by the Concepts in Secondary Mathematics and Science, (CSMS), team has declined over the last 45 years, while performance in other standardized tests has shown improvement. What possible reasons could there be for this disparity?

One explanation that is worth consideration might be that societal change has resulted in a situation where the SRTs are testing student ability in domains that they may have little, or no previous experience in and, just like Dasen's Aborigines, (section 2.2.3), they could be performing below the cognitive level that they might exhibit in other domains as a consequence.

The first ten items of the "*Volume and heaviness*" SRT assess crystallized intelligence, in relation to conservation of mass and volume. Shayer, Ginsburg & Coe, (2007), identified that the typical age range for children acquiring these concepts used to be between 5 and 8; either at home or in school. Development within the domain could be by informal trial-and-error play or through more structured classroom activities. However, many of those classroom activities, such as the sand table, are no longer present, and the reduction in time spent on informal play by children is very noticeable in 2020, when compared to the 1970's.

Television, fifty years ago, was extremely limited in Ireland and the United Kingdom and there were certainly not the opportunities that there are today to substitute active play with sessile, boredom-averting, binge watching; there was no 'Love Island' or the plethora of other televisual opiates that appear to have replaced Marx's expectations for religion.

It was at the beginning of the 1970's that television programming for children began to take off; after a relaxing of broadcasting restrictions that extended viewing time into the day and allowed for the replacement of the test-card with non-peak scheduling for the younger viewer. Even with this, programming was very limited, with a weekly output of around 7 hours on the independent channel, ITV, in 1970 rising to just over 9 hours by 1974. BBC 1, (British Broadcasting Corporation), had half-hour mid-day programmes for the younger viewer, such as *Watch with Mother* which were complemented by RTÉ 1, (Raidió Telefís Éirean), with *Wanderly Wagon*. Late afternoon programmes on BBC and ITV such as *Blue Peter* and *Magpie* were available, but children had to wait until the 1980's before Saturday morning children's television arrived.

In 1975 another opportunity for entertainment appeared in the form of the Home Pong computer game system offered by Atari, and replacing the Magnavox Odyssey; which never really appealed to the public because of it's very limited functionality. By the mid 1970's the home computer game market had found its niche with PC titles such as Space Invaders, Pac-Man and Donkey Kong. The Apple II, Commodore PET and VIC-20, Sinclair ZX80, ZX81 and Spectrum, Atari 8-bit family, BBC, Acorn and Amstrad all entered the lucrative market in the late 1970's and early 1980's. Computer gaming had become a common entertainment pastime for children and young adults.

On the 1st of January 1985 the first mobile phone call was made in Britain, across the Vodafone network, followed in 1986 by calls on Ireland's first mobile network, Eircell. Early devices were very primitive in comparison to the smart phones of the 2020's and indeed, consumers had to wait until 1994 for the first mobile game, Tetris, to appear; followed by Snake in 1997.

Social media platforms were in their infancy at this time and generally restricted to bulletin boards and AOL instant messenger. Skype launched in 2003 and Facebook, developed in 2004, became widely available in 2006. Other platforms included Bebo, (2005), YouTube, (2005), Twitter, (2006), Tumblr, (2007), Instagram, (2010), Snapchat, (2011) and TikTok, (2017).

Ignoring the impact that increased time spent on devices, rather than on active play, has on physical health, and instead focusing on missed opportunities for cognitive development within a range of domains, worrying trends are reported by Ofcom, (2019), the Office of Communications, responsible for the regulation of broadcasting and telecommunications in the UK. In their summary of media use for 2018 they report that children, aged 3 to 7, spent a little over four hours per day watching TV, playing games, or online and that this rose to over five hours for 8 to 11 year olds, and further to just under seven hours per day in the 12 to 15 year age bracket. Game playing was more popular with boys than with girls; with boys in the 12 to 15 age-range spending around seventeen hours per week compared to nine hours for girls of the same age.

Facebook, Instagram and Snapchat all have a minimum age requirement of 13. YouTube and TikTok will permit accounts from 13 year-olds with their parents' permission, but WhatsApp requires users to be 16. Worrying then that Ofcom report that in 2018 children as young as 4 had a social media profile, and state further that 12% of nine-year-olds, 21% aged ten, 34% at eleven and 50% by twelve have an online presence. Vloggers are described as becoming increasingly important go-to sources for information with 15% of three to four year-olds, rising to 52% of twelve to fifteen year-olds, relying on their advice on YouTube. When one adds in all the other demands on the time of children, there is very little left for the type of play that was a characteristic of the early 1970's; and probably even less inclination to indulge in such activities.

In 1988 the Education Reform Act brought significant changes to the education systems in Northern Ireland, England and Wales. These changes involved the introduction of the National Curriculum, which removed a large amount of the flexibility that schools had previously enjoyed in determining what and how they taught their students. With a universal curriculum came the opportunity to assess the *'competences'* of schools in delivering '*quality education'* through the use of compulsory assessments, called standard assessment tests, (SATS), at ages 7, 11 and 14, in English, mathematics and science and with the GCSE, (general certificate of secondary education), at age 16. This change was coupled with open enrolment and league tables that gave parents the opportunity, in theory, to choose where they sent their children. Formula funding was the final component of the reform and this allocated monies on a *per capita* basis. A very similar process was enacted in Ireland, as has already been discussed in section 5.2.2. The net result of these changes appears to have been a move towards teaching-to-the-test, with possibly little regard for other aspects that support cognitive development. Little wonder then for the noted decline in performance on the "*Volume and heaviness*" test.

With regard to "*The pendulum*", Shayer and Ginsberg, (2009, p.414), contend that following the review of the UK National Curriculum in 1995, (not including Scotland), further pressure was put on science teachers to improve SATS scores through teaching the inquiry strand of the curriculum, (SC1), on the basis that only one variable in an experiment should be altered at a time. This author remembers very well the in-service training that indoctrinated this approach. In the earlier responses to questions on "*The pendulum*" about the manipulation of the three variables, length, weight and release, multiple combinations had been offered by students. Shayer and Ginsberg noted that from 1997 these long lists of alternatives had disappeared and that students tended to focus on a single option in their answer. They remind the reader that this cause-and-effect approach is concrete operational by nature and that teaching practices may have inherently limited students thinking to this level.

A further factor that may have influenced performance on "*The pendulum*" task is the increasing risk of litigation over accidents that occur in the playground. It is reported that accidents involving conkers resulted in many UK schools banning their recreational use in 2000; and this was further extended in 2004, through concerns around nut allergies and anaphylaxis. Without the opportunity for children to have previously experimented with factors such as the length of string, power of swing or size of horse-chestnut the likelihood of them performing well on "*the pendulum*" SRT is reduced.

Through regression analysis, Shayer *et al*, (Shayer, Ginsburg & Coe, 2007, p32), place the start of the decline in performance on the "*Volume and heaviness*" task to the mid 1990's. It is feasible to suggest that a direct result of the societal changes discussed in the preceding paragraphs is the observed decline in levels of cognition. If this is the case, then more than at any other time, it would seem imperative to deliver programmes of cognitive acceleration such as *Thinking Science*, (Adey, Shayer & Yates, 2001).

Chapter 6 - Conclusions

6.1 Introduction

The purpose of this research was to develop a student-centred, constructivist learning approach, the student action cycles, (SACs), and to evaluate whether they had any impact on a number of key observables; namely attitudes towards and confidence in the subject, the degree of student collaboration, and cognitive development.

In order to baseline the study, students' perceptions of the ways in which they were taught were also collected. This research was unusual in that partway through the study there was a curriculum change; which saw the junior certificate science syllabus, (JCSS), replaced by the specification for junior cycle science, (SJCS). This provided an opportunity to compare views of both courses, which proved to be enlightening.

6.2 Key findings with regard to students' views on school

> You can please some of the people all of the time, you can please all of the people some of the time, but you can't please all of the people all of the time
>
> John Lydgate (c.1370-c.1451)

In answer to the first research question, 'How closely do specific pedagogical approaches align with students' perceived educational needs and attitudes towards science?' a complex pattern emerged, through the analysis of data from junior certificate and junior cycle students, that indicated that the specification for junior cycle science, (SJCS), was more favoured than its predecessor.

With regard to teaching and learning approaches, students reported a mismatch between pedagogies that they regarded as most effective and enjoyable and those that they were exposed to most regularly, (WLQ1). Copying notes from the board, reading the textbook and taking notes from the teacher were the most commonly employed teaching strategies, while least common, after going on trips, were having debates, looking at videos and making a science presentation. The commonly employed strategies of reading the textbook and copying notes were regarded as least enjoyable by those asked, and they also appeared low down on the scale of useful and effective methods. In fact, the collaborative, active learning approaches, although rated highly by the students as effective, useful and enjoyable, all appeared as the least common classroom experience.

The majority of students expressed a desire for explicit signposting, through the articulation of clear learning outcomes, to help avoid confusion. Exemplars, such as those on the National Council for Curriculum and Assessment, (NCCA), website, success criteria and features of quality, were all mentioned as being particularly valuable in helping to visualise what was expected from them.

When considering social constructivism, students indicated that they spent the majority of their time either listening to the teacher, or working quietly on their own, and that in only about a third of classes, or class time, were there any real opportunities for active co-construction of knowledge through discussion. The position that there should be a variety of teaching and learning approaches within any one lesson was very popular, (WLQ2).

Inquiry based learning approaches, on the continuum from structured through guided to open, were largely regarded as enjoyable and effective pedagogies. The change from the more closed and directed learning outcomes of junior certificate to the general statements from junior cycle, with greater freedom to inquire, were relished by the students and accompanied by an increase in confidence.

Creativity was regarded as more important by first year students than those in sixth year, while diploma disease, in relation to being told what to know to pass, showed the opposite trend, and possibly unsurprisingly, increased in popularity as students moved towards their terminal examination.

With regard to diploma disease, there was strong evidence that measures of performance still held primacy within the classroom, particularly with exam classes, as a significant proportion of individuals reported that they desired only to engage with examinable material, or learn facts, rather than work out solutions, just as long as it got them marks. The active learning strategies of students in the earlier stages of their secondary education were abandoned in favour of being told what to learn for leaving cycle. This indicated that, for whatever reason, rote learning was still the students' preferred pedagogical approach. Whether this continues to be the case with future tranches of students remains to be seen.

Workload was noted to be an increasing concern for students as they moved through the system, with what many regarded as unrealistic expectations being placed on their time as they moved ever closer to the high stakes terminal leaving certificate examinations. Parallel with this, resilience in terms of task perseverance was observed to decline with increasing age.

A retrospective analysis of the junior certificate and junior cycle exam papers by fifth year science classes, containing a mix of students from both courses, identified that the former was regarded as more academically rigorous than the latter. Students appreciated the thinking and creating aspect of junior cycle but were doubtful as to whether the exam, as an indication of the course as a whole, sufficiently prepared them for leaving certificate subjects.

With regard to feedback, and in line with Butler's research, (1988), the overwhelming majority of students stated that they preferred comments that showed them how to improve, to grades. However, numerical scores continued to be asked for, throughout the study, particularly where level descriptors for exams were given, as students stated that numbers would show them how close they were to the next tier of performance.

Comparison of responses to the Trends in International Mathematics and Science Study, (TIMSS), data demonstrated that the junior cycle specification was more popular, than the junior certificate, with students. This was evinced through the increase in numbers of those on the junior cycle course who stated that they enjoyed the subject, regarded it as one of their strengths, or found it easier in relation to other subjects, than had been the case for junior certificate.

When second year students were asked to reflect on their learning and identify the most enjoyable elements of their study the responses predominantly mentioned project work, and in particular the student action cycles, (SACs), they had completed. They also reported that being able to collaborate with their peers, or a more capable individual, helped them most when they were experiencing difficulties with their learning.

6.3 Key findings with regard to attitudes towards science

> Science is nothing but perception
>
> Plato (c.427BC-c.347BC)

Selected questions from the Trends in International Mathematics and Science Study, (TIMSS), and exit tickets on motivational status were analysed to further assess attitudes towards science.

The effect of student action cycles, (SACs), on motivation was found to be relatively small but positive, (r=0.122), when the exit ticket data was compared against that from more traditional units of learning.

Positive endorsement for the use of SACs with junior certificate students was observed in response to TIMSS statements regarding subject enjoyment, (r=0.443), and confidence, (r=0.370), while junior cycle students reported that SACs made the content more accessible, (r=0.292).

The overriding positive influence on motivation, however, appears to have been the introduction of the specification for junior cycle science, (SJCS). The intention of the National Council for Curriculum and Assessment, (NCCA), was to enact a science syllabus that was relevant and connected to students' lives, enjoyable and filled with the potential for engaging learning activities. The results from this study would appear to show that this has been achieved as evidenced by the TIMSS data.

6.4 Key findings with regard to student collaboration

> Many ideas grow better when transplanted into another mind than the one where they sprang up
>
> Oliver Wendell Holmes (1809-1894)

In answer to the second research question, ‘Do student action cycles impact on student collaboration?’, the results from this study show that their use had a small but positive impact, (r=0.242), when compared to work on traditional units of learning. This effect size may have been diminished through the influence of junior cycle, as integral in all subjects are the key skills, which include ‘working with others’. Student collaboration, and classroom noise, are a much more common feature of secondary education in Ireland than they were ten years ago.

Instruments used to evaluate student collaboration included selected questions from the ‘how I feel about school’ survey, (HIFAS), the ‘ways of learning questionnaires’ I and II, (WLQ1, WLQ2), the collaboration survey, reflections on learning, and focus group discussions.

In support of Vygotsky’s position that thought is completed in the word, 75% of students claimed that they found it easier to understand new ideas if they were permitted to discuss them with their friends. Student-speak, as a separate cant from teacher-speak, was recognised as beneficial in developing understanding, as were the opportunities to examine other students’ perspectives and ideas. The impact of reduced self-confidence, or self-esteem, in some students was noted to negatively impact on their preference for group-work, however.

In assessing how much of the school day might be set over to collaborative work, it was found that for only about a third of their time were students encouraged to engage in conversation with their peers.

6.5 Key findings with regard to cognitive development

What we see changes what we know. What we know changes what we see

Piaget (1896 -1980)

In answer to the final research question, ‘Do student action cycles impact on cognitive development?’, the results from this study show that minor gains, (r=0.06), as measured by performance on a pair of science reasoning tasks, (SRTs), were observed. However, due to the nature of the student action cycles involved and in relation to the SRTs, it is most likely that the reported gains were a Type I error due to testing and comparing students’ cognitive abilities across two different domains.

Through application of two SRTs, “*Volume and heaviness*” and “*The pendulum*”, which had been used in a large study across England in the mid 1970’s, a comparison was able to be made with progress through the Piagetian sub-stages in the current student population. The results indicated that a larger proportion of students had not progressed from the concrete operational stage to formal operational thinking than would have been expected forty-five years ago. This observation mirrored recent findings in England and a possible root cause can be ascribed to societal and educational changes that have reduced free-play time and increased a pedagogical approach, in line with diploma disease, of teaching-to-the-test.

Weak to moderate correlations were observed between the results obtained from the SRTs and those from the Drumcondra Reasoning Test, (DRT), or in later years, with their verbal, quantitative, non-verbal and spatial percentiles from the CAT4, (Cognitive Ability Test-4). Comparisons were also made between SRT results and performance in the junior certificate English, mathematics and science examinations, where it was noted that students in the more advanced Piagetian sub-stages generally outperformed those at lower levels.

6.6 Limitations of this research

All attempts to maximise the size of the sample group were taken but one of the limitations of this research was that it was conducted in a single school and the student action cycles, (SACs), by a single teacher. As a result of this, sample sizes, though often in their hundreds, were relatively small. Where possible, parallels were drawn with other sample groups. For example, the data for the whole of Ireland, collected by the Trends in International Mathematics and Science Study, (TIMSS), survey in 2015 was compared with that of the school to establish that the school, indeed, was reasonably representative of the typical Irish population. In addition, data from the science reasoning tasks, (SRTs), both historically and more recently, was held up against that obtained from the school, and from a third level institution to attempt to establish congruence.

There were numerous other possibilities for further exploration that could have been followed by the researcher but it must be considered that his primary role was as a facilitator for the education of the students in his care. This limited the extent to which it was feasible, or warranted, to devote class time to the collection of data.

This research was also dependent on the students' willingness to cooperate with the study and to answer questionnaires, or respond in focus groups, with honesty and candour. While the sample sizes for some of the surveys effectively involved half of the school population, others were much smaller. In some of the longer questionnaires, responder fatigue was noted, with later statements left unanswered, or uniform ticking of the same box from top to bottom of the sheet; in such cases, the whole response sheet was removed from the sample.

Where it was felt that the student being aware that the researcher would know their identity would have affected responses, the questionnaires were completed anonymously. A coding system had been considered, that would enable pre and post intervention data to have been correlated, but it was still the opinion that the closed nature of some of the sample groups would have discouraged free and open commenting if any identifiers, however vague, were included. The limitation imposed by this was that it was not always possible to track and calculate effect sizes. Where identity was not an issue, such as in the SRTs, students were followed.

During the course of the study there were many factors outwith the control of the researcher that could have impacted on the results. And finally, even though this research was conducted over an extended period of time, each of the interventions were fairly short-term in duration.

6.7 Recommendations for future research

The distribution of student mindsets, in this study, was very different from that proposed by Dweck, and therefore a valuable extension of this research would be to extend the study to include other schools. More so, and evidenced by student responses recorded here, further research into the interpretation of the mindset instruments might be beneficial. The wide spectrum of responses to the intelligence questionnaire illustrated that students' perceptions of the word were very diverse and this could have serious consequences for the validity of current mindset instruments. The value in removing confusion caused by the multi-stem statements in Dweck's questionnaire should also be considered.

In December 2020, the international data from the Trends in International Mathematics and Science Study, (TIMSS), will be published. It will be interesting to see whether the data collected in 2019, and recorded in this thesis, is comparable with the Irish data. Further research into the reasons for many of the responses to TIMSS would also be beneficial and might prompt intervention strategies in a number of cases. It is all very well to have the data, but if nothing is done with it to improve the educational experience of the students, then it has empirical value only and is of no practical use.

Data on the cognitive ability of students, as established through application of two of the Concepts in Secondary Mathematics and Science, (CSMS), science reasoning tasks, (SRTs), showed a decline in the level of processing of reality in comparison to that exhibited in 1974. This decline was also noted more recently in England, as discussed in the previous chapters. Many reasons have been offered to explain this and there is a strategy called *'Thinking Science'* (Adey, Shayer & Yates, 2001), that previous research has shown to be effective in reversing the decline. A recommendation for further research would be to examine the implementation of such a programme with students, both at secondary and primary level, to evaluate whether the reports of cognitive acceleration, that it is purported to deliver, could be replicated. It would be the recommendation of this author that an intervention at primary level might be more effective, as evidence from the classroom based assessments, conducted by second year students, shows that students tend to revert to science investigations that they conducted when they were in their primary school.

Finally, it was noted in this study that when students were able to self select their groups for student action cycles, (SACs), and other collaborative work, the output was generally of a higher standard than when groupings were randomised. The most effective collaborative groups were those that contained students of roughly comparable ability. Combinations of most able with least able were generally unproductive, as the students did not communicate effectively with each other; there was generally very little conversation at all. Research into possible impacts of grouping students of similar ability on effective collaboration could be a fascinating, and informative study.

6.8 Coda

In 2020, as a consequence of the SARS-CoV-2 pandemic, Irish secondary school teachers took the unusual step of assessing their own students' performances for the junior cycle and leaving certificate examinations; and did so with equity and without prejudice. The concerns and fears, expressed during stages of the junior cycle curriculum reform, that such a process could and should not be undertaken evaporated in light of far more pressing concerns.

There is a certain irony in that having reached this point in the journey to develop an expansive, collaborative, active and vibrant learning environment for the students in my care, I find myself now masked and separated from the regimented and isolated units that are my socially distanced students: Twenty-four pairs of eyes visible above masks worn to protect against infection. Muted conversation; muttered and muffled reluctant responses to questions posed. No group work. No practical work. A quiet classroom like all the other quiet classrooms in the school: Doors and windows open to allow the air to circulate: The all-pervasive sound of teacher-talk - chalk-and-talk. Textbook, workbook, google-meets, submit online, no-copies, no sharing, no touching, pods, bubbles, single file, use the wipes, sanitise. There is little joy, or laughter in the classes of Autumn 2020: no appetising smells wafting in from home economics this year: no sound of song or instrument from the music department.

This will pass.

For the moment, safety is the priority.

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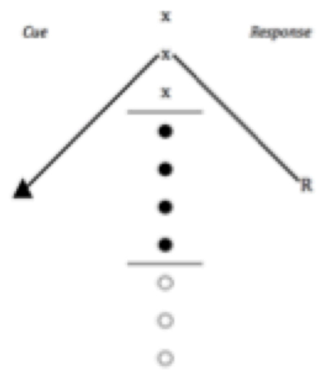
Appendices

Appendix I – SOLO

‘Closer-Colder’

- Ireland is closer to the Sun in January than it is in July.
- It is usually warmer in summer than in winter and the days are longer.
- When it is winter in Ireland it is summer in New Zealand.
- Green plants need sunlight to make food to grow.

Q. Why do plants grow best in summer?

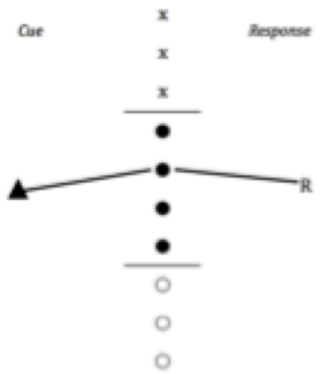
Developmental stage	SOLO descriptor	Response structure
Pre-operational (4-6 years)	Prestructural	
Capacity	*Minimal*: cue and response confused	
Relating operation	Denial, tautology, transduction. Bound to specifics	
Consistency and closure	No felt need for consistency. Closes without even seeing the problem	
Examples of responses	• Because plants don’t grow in winter. • Because the Sun tells them grow. • Because the plants weren’t close enough to the window.	

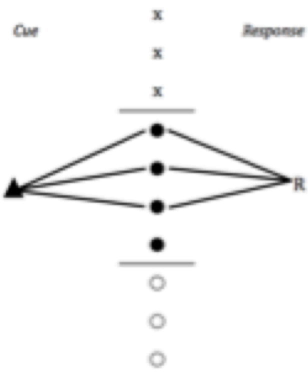
Kind of data used

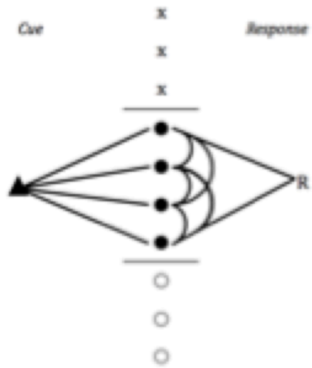
x Irrelevant or inappropriate

● Related and given in display

○ Related and hypothetical, not given

Developmental stage	SOLO descriptor	Response structure
Early Concrete (7-9 years)	Unistructural	
Capacity	*Low*: cue + one relevant datum	
Relating operation	Can 'generalize' only in terms of one aspect	
Consistency and closure	No felt need for consistency, thus closes too quickly: jumps to conclusions on one aspect, and so can be very inconsistent	
Examples of responses	• Plants grow better in summer because it is warmer. • There are more hours of sunlight for the plants to make food in summer so the plants grow better. • Because the Earth is too close to the Sun in winter.	

Developmental stage	SOLO descriptor	Response structure
Middle Concrete (10-12 years)	Multistructural	
Capacity	*Medium*: cue + isolated relevant data	
Relating Operation	Can 'generalize' only in terms of a few limited and independent aspects	
Consistency and closure	Although has a feeling for consistency can be inconsistent because closes too soon on basis of isolated fixations on data, and so can come to different conclusions with the same data	
Examples of responses	• Because the Earth is spinning, Ireland gets more of the sunlight than New Zealand in summer and plants need sunlight to make food. • The change in distance from the Sun in winter and summer has nothing to do with why it is warmer in summer. It is warmer in summer because the days are longer and there are fewer clouds and that is why plants grow best.	

<table>
<tr><th>Developmental stage</th><th>SOLO descriptor</th><th>Response structure</th></tr>
<tr><td>Concrete
Generalization
(13-15 years)</td><td>Relational</td><td rowspan="4">
</td></tr>
<tr><td>Capacity</td><td>High: cue + relevant data + interrelations</td></tr>
<tr><td>Relating operation</td><td>Induction. Can generalize within given or experienced context using related aspects</td></tr>
<tr><td>Consistency and closure</td><td>No inconsistency within the given system, but since closure is unique so inconsistencies may occur when he goes outside the system</td></tr>
<tr><td>Examples of responses</td><td colspan="2">The distance of the Earth from the Sun in its orbit only changes by about 3% between winter and summer and anyway it is further away in summer so this doesn’t explain the seasons. The Earth is tilted on its axis though which means Ireland is facing the Sun and New Zealand is facing away from the Sun in summer. When Ireland is facing the Sun the plants get more sunlight and that is what makes them grow best.</td></tr>
</table>

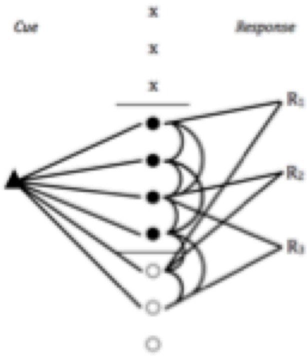
Developmental stage	SOLO descriptor	Response structure
Formal Operations (16+ years)	Extended Abstract	
Capacity	*Maximal*: cue + relevant data + interrelations + hypotheses	
Relating operation	Deduction and induction. Can generalize to situations not experienced	
Consistency and closure	Inconsistencies resolved. No felt need to give closed decisions – conclusions held open, or qualified to allow logically possible alternatives. (R_1, R_2 or R_3)	
Examples of responses	• The Earth is tilted by 23.5 degrees on its axis as it rotates around the Sun. This means that in summer the Northern Hemisphere is angled towards the Sun. Because the Earth's surface is curved, parallel rays of light from the Sun are spread out much further near the poles that they are at the equator. This is why it is cold at the North Pole. The distance of the Sun from the Earth probably makes little difference because there is nothing in space to absorb the energy travelling to Earth. Plants need light for photosynthesis but the rate of this reaction is also affected by temperature I think. This means even if plants got enough light to photosynthesise in Winter, they would probably do it too slowly because it would be cold. New Zealand gets its summer when the North Pole is angled away from the Sun.	

Figure 2.16 adapted from the original in Biggs & Collis, 1982, Evaluating the Quality of Learning: The SOLO Taxonomy (Structure of the Observed Learning Outcome pp 24-25 to include suggested responses to the student action cycle (SAC) trigger scenario 'Closer- Colder'

Task 2 Instructions

Equipment

Glass trough

1000 cm3 cylinder

500 cm3 cylinder

250 cm3 cylinder

100 cm3 cylinder

Maize

4 popcorns

17 x 1 cm wooden cubes

5 x 4 x 3 cm brass/ iron block

2 lumps plasticine 5 x 4 x 3 cm

Perspex 10 x 10 x 10 cm box

2 feet stout thread

250 cm3 beaker

Question 1

A is the 100 cm3 cylinder. B is the 250 cm3 beaker.

Fill A in the tap. Emphasise that it is full. Pour it into B. Refill A. Put A and B alongside each other so that they can be seen. Put the questions.

Question 2

Fill A in the tap. Pour it into D. Refill A. Pour it in C. Refill A. Pour it into B. Refill A. Put all 4 together in a line so they can be seen. Put the questions.

Question 3

Emphasise that popcorn is made straight from the grains. Show them both- maize and popcorn. Let them drop on the bench so that they can hear the solidness of the grains.

Question 4

Make sure top of plasticine block is flat. Show them that 5 1 cm cubes measures the height, and then fit 12 cubes so that they just cover the top of the block. Count them in front of the class. Put the question.

Question 5

Fill the 1000cm3 cylinder to overflowing point and stand in the trough. Show them the plasticine behind or in front of the cylinder just below the water surface (NOT in the water.). Put the question. (Emphasise that the volume of water is what is needed.)

Question 6

Use the thread to hang the plasticine block lengthways, by using it like a cheese cutter. Lower it into the water, showing the water overflowing. Remove the plasticine and refill to overflowing point. Put the question (Emphasise that it is the volume of the water that is wanted.)

Question 7

Pour water out of the cylinder until 500 cm3 remains. Say 'If I lower the plasticine into the water until it is just under the surface, what will the water level in the cylinder be?'

Question 8

Actually roll the plasticine to make a sphere so that they can see you do it. Put the question (as compared with question 7)

Question 9

Roll the plasticine to a long thin sausage shape. Put the question (as Q. 7)

Question 10

Pass the metal block together with the plasticine block round the class so that they can 'weigh' both in their hands. Refill the 1000 cm3 cylinder to the top.

Question 11

Squeeze the plasticine so it makes a disc about 10 cm in diameter. Have the trough half full with water. Ask first question.

Then lower it in. (it sinks) Take it out. Remove about 1/3 of it. Squeeze this 1/3 into an even thinner disc. Put the second question, but do not demonstrate.

Then take off a very small piece, so that squeezed as thin as will still hold together it is about 1 cm across. Show it to them and ask the third question.

Question 12

Show the 10 x 10 x 10 cm box. Say it is so light that they can forget about its own weight. Emphasise that the second box in question is just like it, but twice as tall. Repeat the information in question a. Show the box again and put the first question.

Emphasise that it is very important to show the working/ reasoning being used.

When they have finished show the box again and read question b.

Question 13

This is a version of Archimedes and the King. Tell them that the King had a new crown made, which was supposed to be bigger and better than his old one. However, when it arrived the King suspected that his goldsmith has stolen some of the gold and mixed in some lighter metal (copper?) to make the weight up again. The King asked Archimedes to find out if the new crown was pure gold. Archimedes then set about measuring separately the volume of each crown, and the weight of each crown. Put the questions. If pupils ask, say he made a measuring cylinder large enough to a crown in.

Question 14

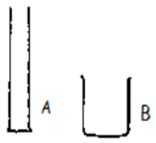
Explain that A and B are both made of the same metal, but the illustrations are not the same scale, so they cannot get the answer by looking at them. Put the question. Again, as in 12, they must show or explain how they get their answer.

Name: .... Date of Birth: ....
Class: .... Teacher's Name: ....
School: .... Secondary School you may go to: ....

Science Reasoning Task 2

Please tick what you think is the best answer.

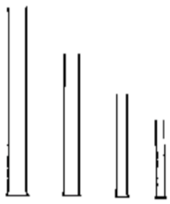
1.



A has...
more ☐
less ☐
the same ☐

.. amount of water compared with B.

2.



D C B A

Do these cylinders all have the same amount of water?

Yes ☐ No ☐

If you answered 'NO' write down which has the most?

.... (A/ B/ C/ D)

3.

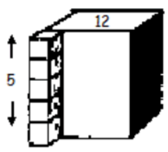
(a) The pop- corns have..
less ☐
more ☐
the same ☐
..amount of maize, compared with the grains.

(b) The pop- corns weigh
less ☐
more ☐
the same ☐
.. compared with the grains.

Explain your answer.

....
....

4.



What is the volume of this plasticine block, in cubic centimetres?

Show your workings here.

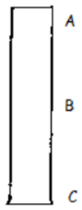
Your answer ....

Correct answer ....

5. How much water will spill over when the plasticine is all under water?

....

6.

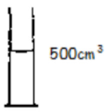


You see that water spills over when the block is lowered to A.

If it is lowered to B instead, will more ☐ / less ☐ / the same ☐ amount of water spill over.

If it is lowered to C instead, will more ☐ / less ☐ / the same ☐ amount of water spill over.

7.

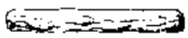


What will the new volume reading be?

....

8. If the plasticine is made into a ball, will the level of water be the same ☐ / higher ☐ / lower ☐

9. If the plasticine is made into a cylinder, will the level of water be the same ☐ / higher ☐ / lower ☐



10. If the metal block is lowered in, will more ☐ / less ☐ / the same ☐ amount of water spill over?

Why do you think so?

....

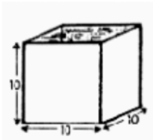
11. **(a)** Will this flat piece float ☐
sink ☐ ?

(b) Will this small flat piece float? Yes ☐ No ☐

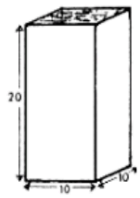
(c) Will this tiny piece float? Yes ☐ No ☐
Why do you think so?
……………………………………………………………………………

---

12. **(a)** This box, full of washing-up liquid weighs 1500 grams.

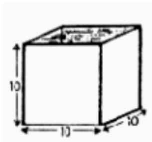


Another box (twice as tall) filled with water weighs 2000 grams



Would the box with the washing- up liquid float ☐
Sink ☐ in water?

How did you work out your answer?
……………………………………………………………………………
……………………………………………………………………………



(b) When this box is emptied, and filled with alcohol it weighs 850 grams.

Will it float ☐
sink ☐ in water?

How did you work out your answer?
……………………………………………………………………………
……………………………………………………………………………

13. **(a)**

How do you think Archimedes measured the old and new crowns' volumes to compare them, using a measuring cylinder?

....

....

....

....

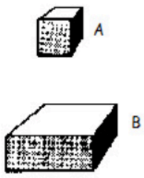
....

(b) Archimedes then weighed the two crowns and found that the new, bigger crown weighed more than the old one. Nevertheless he said that the new crown has some lighter metal in it.

How do you think he worked it out?

....

14.



Both blocks are made of the same brass.

A weighs 60 grams, and its volume is 15 cm^3.

B weighs 160 grams.

What is its volume? .... cm^3

How did you work out your answer?

....

....

Science Reasoning Task

Task III

This task investigates the students' ability to sort out the effects of three variables: how the length, weight and push of a pendulum determine the period of oscillation (period of swing). Only the length is important but the student has to overcome strong intuitive feelings in order to realise this. The task should take approximately 45 minutes.

Materials:

Stopclock

2 weights (e. 100g and 400g on hangers)

2 strings looped at either end (Loop to loop distances of 69cm and 35 cm will give about 17 and 22 swings in half a minute)

Firm support to hang pendulum from.

Administration

There are not many questions in this TASK, so your skill as a teacher should be used for creating a comparatively relaxed and slow- moving situation in which the students get the maximum opportunity to reflect on the questions which are asked. At any stage feel free to re- phrase any question in any way, so that the problem for the students is the one on the page, and not that of understanding what the question is about. Here we are trying to maximise the possibility of finding the same range of responses which one might obtain by individual interview.

1.

Introduce the Task as a series of experiments to find out what factors determine how fast a pendulum swings. Talk through the first pages showing them the combinations, with your apparatus, which are given on the cover of their response sheets. "Gentle" and "Hard" may seem loose to you as a trained scientist but they do not worry the students. Occasionally at the end of the Task a few students complain that the push was not standardised, but there is no evidence to indicate that their performances were affected. Make sure they understand that 'how fast' means "How many swings in a given time" and not the velocity of the weights while swinging. Ask them to turn over, and write in the first combination of variables in the columns in the box opposite, and to make a wild guess about the number of swings. Perform the experiment by starting the weight at the bottom, and swinging it very gently out (keep a slight tension on the string so that it doesn't 'bounce'). Time whole swings, "Zero", "One", "Two", etc., and stop the pendulum after ½ a minute. Round off the number of swings to a whole number. Ask students to record the result.

2.Ask them to write in the new combination of variables in the box opposite, tell them that their guess is again a 'free' one, and is just there to help them think, and perform as in 1. Again, ask students to record the result.

3.Ask for their ideas about how the three variables affect the number of swings. We want answers of the form: "If its longer then ……"
* The first three questions (1, 2, 3) are not assessed but are designed to help focus the students attention on the problem.

4.It is hoped that by asking for their ideas in question 3 some students will then distinguish between their ideas and the evidence in 4. They will probably think that the two questions are the same, so point out that " here we are interested in what, if anything, this particular couple of experiments show". If they feel they have already answered this question, then of course they can write "see above". The "if anything" is a hint to the intelligent child who might be worried that he/ she must deduce something from every experiment. Do not labour the point.

5. Make sure they realise that there are THREE parts to their answers. (1) a new combination of Length, Weight and Push, (2) a reason for choosing it, and (3) an explanation of how it ties in with the first two.

6& 7. This page tests their experimental economy, (a typical concrete operational strategy is to 'try everything') and their awareness that variables must be controlled. Explain in your own words that here we are trying to find out how they would have investigated this on their own. "How would they plan the experiments?" Let them write their combinations, and then draw their attention to the note in brackets, about being economical.

8.Say that for this pendulum the "LONG", "HEAVY", etc. weren't quite the same as for the one you demonstrated, ask them to imagine they are looking critically at someone else's experiment so that they cant compare the values with 1 and 2. In this question we get the 3A response from the last part of the question, so for the question "What do they tell us about the effect of the PUSH?" emphasise that it is just these two results they should use, and ask them for a fairly explicit answer i.e. their deduction and also their reason for making it. This gives them the opportunity to give us a 3B response by pointing out that no proper deduction can be made. Read through the last part. Make sure they have all finished, and only then ask them to turn over to the last side.

9.This question, page 4 is the most crucial part of the Task. Two more combinations of variables are demonstrated, and then Question 10 tests their ability to analyse the data reflectively. Here is where most of the evidence is gained as to whether a student is using late Formal Operational thinking.

Note that the 4 combinations set up in Question 9&10 control the variables so as to allow for unambiguous deductions about the effect of LENGTH (Exp. 2

& 4) and WEIGHT (Exp. 1 & 4), but appear not to control the other variables in respect of PUSH. IN fact, once the effect of WEIGHT has been deduced, then Exp 2 and 3 can be used to deduce the (non) effect of PUSH, and the pupil is given a chance to show this, either in 10. (e) or in (g). It is difficult to spot that the evidence is still sufficient for PUSH, so in (g) a 3B assessment can be reached by the alternative strategy of explaining that, for PUSH, the other variables were not controlled.

It is important that the data is as clear as possible. Ask them to write in the values from 1 and 2, to fill in the details for 9 (c) ,and to have a guess about the number of swings. Remind them that their guesses are not assessed, but are designed to help them in their thinking: if their guess is close to the experimental result then their thoughts are probably on the right track, but if not, then they know that they have to think again. Demonstrate 9 (c) and ENSURE that the answer is the same as 9 (b), ask them to record. For the Hard push, swing the pendulum about 30° from the vertical. Repeat the above for 9 (d) and this time make sure the answer is the same as 9 (a).

Explain in your own words that using just these four experiments we want them to deduce the effect, and direction of each factor. E.g. "If you think they show that weight has an effect, then don't just write 'it has an effect' but say 'If the weight is heavier then you get fewer/more swings in half a minute'". Explain also that different combinations of the four experiments may be necessary for their various conclusions. Ask them to write in the box labelled "experiments" only those (from 9 (a)- (d)) they really need in order to make their deductions.

9(g) In your own words point out that "maybe you found one of the factors rather more difficult to determine than the other two. If so, say which (and if not, that's OK), and then you've a choice of answers. EITHER show how you used the evidence to make your deduction, OR explain why you think the data is insufficient".

NB. It is most important that you ensure that the number of swings recorded in 9 (b) is the same as that in 9 (c), and that 9 (a) is the same as 9 (d). Otherwise students cannot make valid deductions in 10 (a- g).

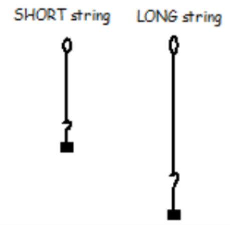
Name: _______________ Class: ____________

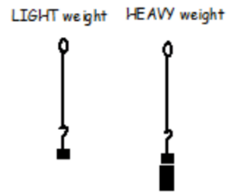
School: _______________Teacher's Name: _______________

Date of Birth: _________ Primary School attended: __________

Science Reasoning Task III

We are going to make a pendulum, using a SHORT or LONG string,
and a LIGHT or HEAVY weight,
and we will give it a LOW or HIGH release.





1. SHORT string, HEAVY weight, LOW release.
   How many swings in 30 seconds? Your guess: ______________

   Experiment 1

Length	Weight	Release	Number of swings in 30 seconds

2. LONG string, LIGHT weight, LOW release.
   How many swings in 30 seconds? Your guess: ______________

   Experiment 2

Length	Weight	Release	Number of swings in 30 seconds

3. **What effect do you think LENGTH, WEIGHT, and RELEASE have on the number of swings in 30 seconds?**
   LENGTH:

   WEIGHT:

   RELEASE:

4. Now what can we tell, if anything, just from these experiments, about the effect of LENGTH, WEIGHT and RELEASE on the number of swings?

   LENGTH:

   WEIGHT:

   RELEASE:

5. Write down one more experiment that you think would be worth trying next, and explain why you have chosen it. Also explain how this new experiment ties in with experiment 1 and 2:

20

6.
Imagine that we start again with Experiment 1

Which other arrangements would you use to test the effect that LENGTH has on the number of swings?

Length	Weight	Release	Number of swings in 30secs
Short	Heavy	Low	

7.

Again starting with Experiment 1 how would you test for the effect that WEIGHT has?

Length	Weight	Release	Number of swings in 30 secs
Short	Heavy	Low	

8. Imagine the scientist tried these 2 arrangements (with another pendulum)

What do they tell us about the effect of the RELEASE?

....

....

....

....

If there are any other arrangements that you think you would really need to be sure of the effect of the RELEASE, write them down.

Length	Weight	Release	Number of swings in 30 secs
Long	Heavy	High	15
Short	Heavy	Low	20

9.

		Length	Weight	Release	Number of swings in 30sec
(a)	Experiment 1	Short	Heavy	Low	
(b)	Experiment 2	Long	Light	Low	
(c) LONG string, HEAVY weight, HIGH release. Your guess: ________ swings	Experiment 3	Long	Heavy	High	
(d) SHORT string, LIGHT weight, LOW release. Your guess: ________ swings	Experiment 4	Short.	Light	Low	

10. Now write down what these four experiments alone tell us about the effect of LENGTH, WEIGHT and RELEASE on the number of swings, and for each factor, note down only those experiments that you need to use:

(a) LENGTH: (b). Experiments:

(c) WEIGHT: (d). Experiments:

(e) RELEASE: Experiments:

Is the evidence weaker for deciding about one of the factors than it is for the others?

Yes ☐ No ☐

If so, say which factor: ____________________

and

EITHER show that the evidence is still sufficient, OR explain why it is insufficient.

Thank you =)

Appendix III – How I feel about school, (HIFAS)

		Not at all like me	Not very much like me	Somewh at like me	Fairly much like me	Very much like me
1	I worry that I might fail my classes					
2	I don't care whether I understand my work as long as I remember enough to get good marks in tests					
3	I find that when my teachers are talking I think of other things and don't really listen to what is being said					
4	I find it easier to understand new ideas if I talk them through with my friends					
5	I get discouraged if I get low marks					
6	I prefer comments, that show me how to improve, over grades					
7	I am up to date with all my school work					
8	I only want to learn stuff that will come up in exams					
9	My mind wanders a lot when I am doing schoolwork					
10	I only study the subjects I like					
11	I like to be told what I am expected to learn in class					
12	I prefer to use a textbook to searching for information on the internet with my Ipad					
13	I don't understand some stuff from lessons because I don't always listen to my teachers					
14	I prefer classes where I can share and compare ideas with my friends					
15	I like project work because it allows me to be creative					
16	I think it is more important to know the answer than how to work it out					
17	When work gets hard I give up or only study the easy bits					
18	I set high standards or goals for myself with schoolwork					
19	I am not easily distracted from work					
20	I prefer tests that ask me to write down facts that I have been told to tests that ask me work something out					
21	I believe a good student should never question the teacher					
22	I often get confused as to what I am expected to learn in class					
23	I often feel I have little control over my learning					
24	I believe that if I work hard I can improve my skills whatever the subject is					
25	I believe that exam success depends more on the teacher I have than on my ability					
26	I like challenges that are difficult and require me to work hard to solve					
27	In my opinion, most of what is taught in class is not worth learning					
28	It is more important to me to impress my teacher or parents by my success in exams compared to learning new skills					
29	I always do my homework					
30	I don't like to share my ideas because others might not agree with me					
31	Even when I am taking a test that I am well prepared for I feel upset					
32	I think the only way a teacher can know how I am doing is by giving me tests					
33	I think that how well I do in school depends more on how clever I am than how hard I work					
34	The best classes are the ones where I can learn by talking rather than learn by listening					

		Not at all like me	Not very much like me	Somewhat like me	Fairly much like me	Very much like me
35	I think that learning the skills to solve a problem is more important than knowing the answer					
36	I think you can learn new skills but not really change how intelligent you are					
37	I would prefer to show my skills and understanding by project work to taking exams					
38	I like to be given challenging problems to solve					
39	I often have trouble making sense of things I have to remember					
40	Much of what I learn seems to be unrelated bits and pieces that I can't see the purpose for knowing					
41	I take what I am being taught at face value without questioning it					
42	I find it easy to know whether or not I have learned what I am supposed to					
43	I often set goals for myself					
44	I reflect on my learning to help me improve					
45	I like the opportunity to redo work to make it better					
46	When I am working I don't notice time passing					

Appendix IV – Motivation questionnaire

Motivated :_1_:_2_:_3_:_4_:_5_: Unmotivated

Interested :_1_:_2_:_3_:_4_:_5_: Uninterested

Involved :_1_:_2_:_3_:_4_:_5_: Uninvolved

Excited :_1_:_2_:_3_:_4_:_5_: Bored

Dreading it :_1_:_2_:_3_:_4_:_5_: Look forward to it [R]

Appendix V – Diehl's Mindset Quiz, (DMQ)

Mindset Quiz

Place a check in the column that identifies the extent to which you agree or disagree with the statement.

	Strongly Agree	Agree	Disagree	Strongly Disagree
1. Your intelligence is something very basic about you that you can't change very much.				
2. No matter how much intelligence you have, you can always change it quite a bit.				
3. You can always substantially change how intelligent you are.				
4. You are a certain kind of person, and there is not much that can be done to really change that.				
5. You can always change basic things about the kind of person you are.				
6. Music talent can be learned by anyone.				
7. Only a few people will be truly good at sports – you have to be "born with it."				
8. Math is much easier to learn if you are male or maybe come from a culture who values math.				
9. The harder you work at something, the better you will be at it.				
10. No matter what kind of person you are, you can always change substantially.				
11. Trying new things is stressful for me and I avoid it.				
12. Some people are good and kind, and some are not – it's not often that people change.				
13. I appreciate when parents, coaches, teachers give me feedback about my performance.				
14. I often get angry when I get feedback about my performance.				
15. All human beings without a brain injury or birth defect are capable of the same amount of learning.				
16. You can learn new things, but you can't really change how intelligent you are.				
17. You can do things differently, but the important parts of who you are can't really be changed.				
18. Human beings are basically good, but sometimes make terrible decisions.				
19. An important reason why I do my school work is that I like to learn new things.				
20. Truly smart people do not need to try hard.				

Circle the number in the box that matches each answer.

	Strongly Agree	Agree	Disagree	Strongly Disagree
1. ability mindset – fixed	0	1	2	3
2. ability mindset – growth	3	2	1	0
3. ability mindset – growth	3	2	1	0
4. personality/character mindset – fixed	0	1	2	3
5. personality/character mindset – growth	3	2	1	0
6. ability mindset – growth	3	2	1	0
7. ability mindset – fixed	0	1	2	3
8. ability mindset – fixed	0	1	2	3
9. ability mindset – growth	3	2	1	0
10. personality/character mindset - growth	3	2	1	0
11. ability mindset – fixed	0	1	2	3
12. personality/character mindset – fixed	0	1	2	3
13. ability mindset –growth	3	2	1	0
14. ability mindset – fixed	0	1	2	3
15. ability mindset – growth	3	2	1	0
16. ability mindset – fixed	0	1	2	3
17. personality/character mindset – fixed	0	1	2	3
18. personality/character mindset –growth	3	2	1	0
19. ability mindset – growth	3	2	1	0
20. ability mindset – fixed	0	1	2	3
Total				
Grand Total				

Strong Growth Mindset =	45 – 60 points
Growth Mindset with some Fixed ideas =	34 – 44 points
Fixed Mindset with some Growth ideas =	21 – 33 points
Strong Fixed Mindset =	0 – 20 points

Adapted from:

http://www.classroom20.com/forum/topics/motivating-students-with

Appendix VI – Dweck's Mindset Instrument, (DMI)

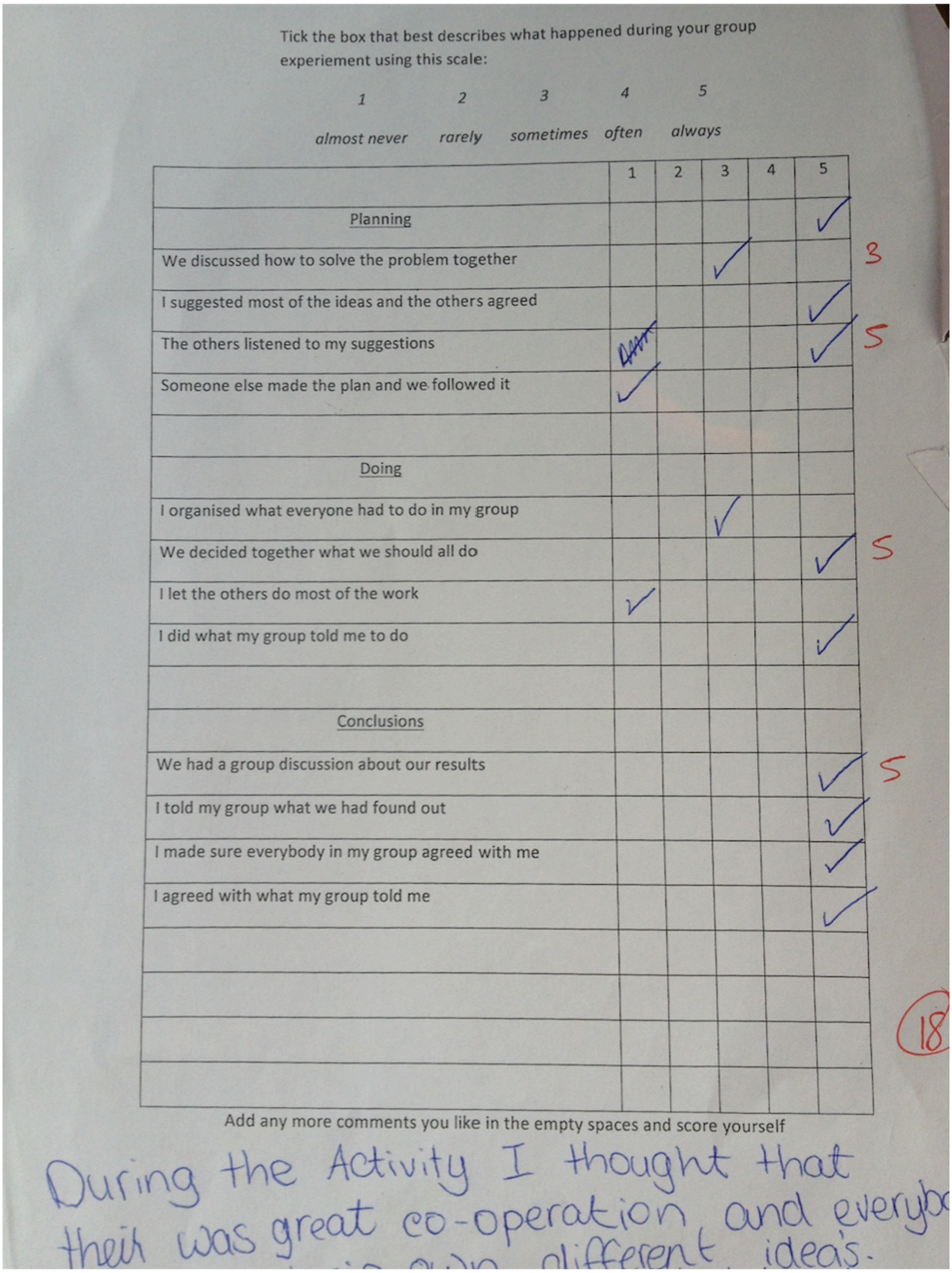
DWECK MINDSET INSTRUMENT

Directions: Read each sentence below and then mark the corresponding box that shows how much you agree with each sentence. There are no right or wrong answers.

	1 Strongly Agree	2 Agree	3 Mostly Agree	4 Mostly Disagree	5 Disagree	6 Strongly Disagree
1) You have a certain amount of intelligence, and you really can't do much to change it.						
2) Your intelligence is something about you that you can't change very much.						
3) No matter who you are, you can significantly change your intelligence level.						
4) To be honest, you can't really change how intelligent you are.						
5) You can always substantially change how intelligent you are.						
6) You can learn new things, but you can't really change your basic intelligence.						
7) No matter how much intelligence you have, you can always change it quite a bit.						
8) You can change even your basic intelligence level considerably.						

	1 Strongly Agree	2 Agree	3 Mostly Agree	4 Mostly Disagree	5 Disagree	6 Strongly Disagree
9) You have a certain amount of talent, and you can't really do much to change it.						
10) Your talent in an area is something about you that you can't change very much.						
11) No matter who you are, you can significantly change your level of talent.						
12) To be honest, you can't really change how much talent you have.						
13) You can always substantially change how much talent you have.						
14) You can learn new things, but you can't really change your basic level of talent.						
15) No matter how much talent you have, you can always change it quite a bit.						
16) You can change even your basic level of talent considerably.						

Appendix VII – Collaboration survey



Tick the box that best describes what happened during your group experiement using this scale:

1	2	3	4	5
almost never	*rarely*	*sometimes*	*often*	*always*

	1	2	3	4	5	
Planning					✓	
We discussed how to solve the problem together			✓			3
I suggested most of the ideas and the others agreed					✓	
The others listened to my suggestions	~~✓~~				✓	5
Someone else made the plan and we followed it	✓					
Doing						
I organised what everyone had to do in my group			✓			
We decided together what we should all do					✓	5
I let the others do most of the work	✓					
I did what my group told me to do					✓	
Conclusions						
We had a group discussion about our results					✓	5
I told my group what we had found out					✓	
I made sure everybody in my group agreed with me					✓	
I agreed with what my group told me					✓	
						18

Add any more comments you like in the empty spaces and score yourself

During the Activity I thought that their was great co-operation and everybo... different idea's.

Appendix VIII – Ethics

Catherine O'Rourke <CAOROURK@tcd.ie> Wed, 2 Jul 2014, 16:16

to CLARKR11@tcd.ie, Colette

Dear Robert,

I am in receipt of your research ethics approval form and note that your supervisor has signed off indicating that no further action is needed on the part of the Research Ethics Committee. Therefore, ethics approval is granted for your project on condition that it is carried out as indicated on your approval application.

Should there be a change in your research project design you will need to apply again for ethics approval. You will be required to sign a statement on submission of your thesis to declare that the research was carried out using the design and methods approved.

Best wishes for the success of your project.

Kind regards,

Catherine,
on behalf of Professor Colette Murphy,
Director of Research.

Catherine O Rourke
School of Education

Flipped-Mastery in the mixed ability classroom within the context of Secondary Level Science in Ireland.

Dear Parent/Guardian

This letter provides information about research being undertaken by Mr. Robert Clarke, with the informed consent of the Board of Management of Community College and under the supervision of Dr. Colette Murphy, Director of Research in the School of Education at Trinity College Dublin, into Flipped-Mastery Learning in Science and asks you to provide consent for your son/daughter to take part.

Q. What is Flipped-Mastery Learning ?:

Flipped Learning originated in America and is a teaching approach where the standard classroom instruction is given by video or podcast to be studied and learnt at home allowing class time to be used more constructively to develop better understanding of the material. Among the suggested benefits of this approach are the possibilities for students who are working with challenging concepts to pause, rewind and review material as often as is needed and then work through their ideas with their peers in the classroom.

Mastery Learning is a separate approach that allows students to progress through the course material at a pace and in an order determined by themselves, demonstrating their knowledge and understanding through tests, or other means, to the satisfaction of the teacher before starting new work. Students will still be required to complete the course material prescribed for the year to an appropriate standard but are able, using this approach, to spend less time in areas they have mastered and more time where they are having difficulty or where they have a particular interest.

Both these approaches firmly address what the National Council for Curriculum and Assessment, (NCCA), regard as Key Skills that students should posses and which the NCCA have grouped under the headings of: Managing Myself, Staying Well, Communicating, Being Creative, Working with Others and Managing Information and Thinking.

Combining the two approaches into Flipped-Mastery Learning provides the opportunity to compliment the benefits of each method and potentially provides your son/daughter with an accessible and engaging experience that promotes understanding, attainment and enrichment. More information about Flipped-Mastery Learning can be found at http://www.XXXXXXXXX/parents-information.html

Q. How will this study involve my son/daughter ?:

If you agree for your son/daughter to take part then periodically he/she may be asked to complete an online survey or Reflection on Learning, participate in an interview or focus group or be filmed/audio-recorded while undertaking group work in class. Not all First Year classes will be flipped and to help assess the academic merit of the process it is intended that results across the Year Group in common tests will also be compared.

Q. How much time will this take ?:

Participation in the online surveys, which are designed to take about 5 minutes to complete and anonymous, will take place no more than once a month. Reflections on Learning will only be expected from students using efolios, namely those in the Flipped Group. Students will be chosen at random for interview or focus group participation and these sessions are intended to last no longer than 20 minutes and be conducted no more frequently than once a term. Audio and video recording participation will also be selected randomly, but taping is not required for your child to be part of the study, and will focus on what students are doing and saying while undertaking practical tasks or group activities; as such there will be no specific time requirement outside normal classroom hours.

Q. How will my son/daughter benefit from being part of this study?

While your child may not directly benefit from participating in this project, it is hoped that this study will contribute to effective planning, policy and practice within the school to enhance teaching and learning.

Q. Are there any risks associated with my son/daughter taking part in this study?

There are no risks associated with this study because the topic is not sensitive and the data collection is either completely anonymous or non-confidential.

Q. What will be done with the data collected?

It is intended that results and conclusions drawn from this study will form the basis of research papers that may be published in education journals but these will not include any information that would identify you or your son or daughter. At the end of the study, what has been learnt will be shared with all participants. This will be done first by meeting with the participants and then through a written report which will be made available on request. It is also intended that the results and conclusions of this study be publish in a research thesis as part of the conditional requirements for the award of the degree of Doctor of Philosophy at Trinity College Dublin by the researcher.

Q. What about the Data Protection Act and Confidentiality ?:

None of the data collected, such as test scores, comments from interviews or reflections will be shared or otherwise disseminated to other members of the study group or anyone else in a form that would identify your son or daughter. Under the terms of the Data Protection Act you have the right to request a copy of all information collected and recorded relating to your child.

Data will be kept on a password-protected computer using special software that scrambles the information so that no one other than the researcher can read it.

The audio record of your child's interview or focus group participation will be placed in a locked file cabinet until a written word-for-word copy of the discussion has been created. As soon as this process is complete, the recording will be erased. To protect confidentiality, your child's real name will not be used in the written copy of the discussion.

Video of your son or daughter's participation in class activities will also be encrypted and destroyed after it has been analyzed unless there are sections that would be particularly valuable for teacher education. The standard conditions as set out in this letter referring to anonymity would still apply and your specific approval for the use of any section, with an explanation to the purpose it would be used for, would be requested from you before it would be used. You would obviously be shown the videoed section to allow informed consent for its use.

Raw data such as individual test scores will be retained for the duration of your son/daughter's time in the Junior Cycle program as is standard practice within the school. Other raw data such as that collected from surveys will be destroyed immediately after it has been collated.

There are some reasons why people other than the researcher may need to see information your child provides as part of the study. This could include the school principal, Mr. , the research supervisor, Dr. Murphy or the School of Social Sciences and Philosophy Ethics Committee of Trinity College Dublin all of whom are responsible for making sure that the researcher is conducting the study safely and with due diligence.

Q. Is participation in the study compulsory?

No, participating in this study is completely voluntary. Even if you decide to permit your son/daughter to participate now, you may change your mind and stop this at any time in the future. If you decide to withdraw early the information or data that has been collected from your child will be destroyed unless this information or data cannot be destroyed because it is not linked to your son or daughter either directly or by a code.

If you have questions about this research you can contact Robert Clarke at Community College, by phone on , or by email to clarkr11@tcd.ie.

Yours sincerely,

Robert Clarke

Parental Permission

By signing this document, you are agreeing to allow your son or daughter to be part of the study entitled '*Flipped-Mastery in the mixed ability classroom within the context of Secondary Level Science in Ireland'.* You are confirming that you have read the forgoing information and that you have been given the opportunity to ask questions about it and any questions that you have asked have been answered to your satisfaction. You may contact the researcher if you think of a question later. You understand that your child's participation in this study is completely voluntary. If you allow your child to be part of the study, you may change your mind and withdraw your approval at any time. Your child may choose not to be part of the study, even if you agree, and may refuse to answer interview questions or stop participating at any time if he or she so wishes.

You will be given a copy of this document for your records and one copy will be kept with the study records.

I _________________________________ (print your name) (do not)* give my permission

for my child__________________________________ (print your child's name) to

participate in this study.

_________________________________ ______________________

Signature Date

I (do not)* give my permission for the interview with my child to be audio recorded.

_________________________________ ______________________

Signature Date

I (do not)* give my permission for my child to be video recorded during class group and practical activities.

_________________________________ ______________________

Signature Date

* delete as appropriate

Flipped-Mastery in the mixed ability classroom within the context of Secondary Level Science in Ireland.

Principal Investigator: Mr. Robert Clarke

Overview and purpose

I am asking you to be part of a research study that is looking at how effective a different teaching approach is in helping students to learn. The study will compare progress and attitudes to learning in different science classes. I am asking all students in First Year to participate in this research. This study is being done as part of my research degree program at Trinity College Dublin.

Description of your involvement

If you agree to be part of this study and at least one of your parents gives permission, you may occasionally be asked to complete a short online survey in class that should not take more than about 5 minutes. If you are in my class then you will be expected to briefly write about what went well and possibly what didn't go so well with learning as a reflective blog on your web-site for homework once a month. You may also be asked to take part in a short interview about your views and this would be recorded and then transcribed later; this is to make sure that our conversation is recorded accurately. Occasionally you might be asked to be a member of a focus group. This means a number of students including you would be asked to give your opinions about the way you are learning your science. You might also be asked to allow video recording of your participation in group work or in practicals to take place.

Benefits

While you may not receive a direct benefit from participating, I hope that this study will result in developing better methods for learning and teaching science.

Risks

Nothing will be asked of you that will place you in danger and neither will any information of a personal nature be requested. You can choose not to answer questions or you may stop an interview at any time.

Confidentiality

I plan to publish the results of this study, but will not include any information that would identify you. To keep your information safe, the audio recording of your interview will be placed in a locked file cabinet until a written word-for-word copy of the discussion has been created. As soon as this process is complete, the recording will be erased. I will enter study data on a computer that is password-protected. To protect confidentiality, your real name will not be used in the written copy of the discussion.

There are some reasons why people other than myself may need to see information you provide as part of the study. These include Mr. , Dr. Murphy, my supervisor, and also the Ethics Committee at Trinity College Dublin who are responsible for making sure that I carry out this research safely and properly and with no risk to you.

Voluntary nature of the study

Participating in this study is completely voluntary. Even if your parents say you can take part, you do not have to do so. Even if you say yes, you may change your mind and stop at any time. You may also choose not to answer a question for any reason.

Contact information

If you have questions about this research you can come and see my during school time or send me a request for an answer here:

http://www.XXXXXXXX.com/help.html

Assent

By signing this document, you are agreeing to be in the study. I will give you a copy of this document and will keep a copy in the study records. Be sure that I have answered your questions about the study and you understand what you are being asked to do. You may contact me at any time if you think of a question later.

I ______________________________________(print name)

(don't) agree to participate in this study.*

____________________ (sign) ____________________ (date)

I (don't) agree to have my interview audio recorded*

____________________ (sign) ____________________ (date)

I (don't) agree to video recording of group work and practical activities.*

____________________ (sign) ____________________ (date)

* delete as appropriate

Appendix IX – Ways of learning questionnaire 1, (WLQI)

Ways of learning questionnaire

1) Look at the options below and choose **three** options that you think are most **useful and effective** for your learning:

	Taking notes from the teacher
	Looking at videos
	Reading the textbooks
	Taking my own notes from books etc.
	Copying notes from the board
	Doing research or a science investigation
	Making a presentation to the class
	Using the Internet
	Going on a trip
	Doing an experiment in class
	Having a discussion/debate in class

2) Look at the options below and choose **three** options that you think are most **enjoyable** for your learning:

	Taking notes from the teacher
	Looking at videos
	Reading the textbooks
	Taking my own notes from books etc.
	Copying notes from the board
	Doing research or a science investigation
	Making a presentation to the class
	Using the Internet
	Going on a trip
	Doing an experiment in class
	Having a discussion/debate in class

3) If you have other ways that are more useful or effective please write them here

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4) If you have other ways that are more enjoyable please write them here

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Appendix X – Ways of learning questionnaire 2, (WLQII)

Ways of learning questionnaire -2

1) Look at the options below and choose **three** options that **you do most often in classes** – put them in order 1, 2, 3

	Taking notes from the teacher
	Looking at videos
	Reading the textbooks
	Taking my own notes from books etc.
	Copying notes from the board
	Doing research or a science investigation
	Making a presentation to the class
	Using the Internet
	Going on a trip
	Doing an experiment in class
	Having a discussion/debate in class

2) Look at the options below and choose **three** options that **you do least often in classes** – put them in order 1, 2, 3

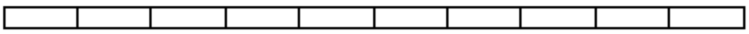
	Taking notes from the teacher
	Looking at videos
	Reading the textbooks
	Taking my own notes from books etc.
	Copying notes from the board
	Doing research or a science investigation
	Making a presentation to the class
	Using the Internet
	Going on a trip
	Doing an experiment in class
	Having a discussion/debate in class

3) Think about all your lessons and shade in the bar chart to show the average for **listening to teacher**, **working quietly**, and **talking and working in a group:**

Eg: if you spend 20% **listening to teacher**, 20% **working quietly** and 60% **talking and working in a group**, your chart would look like this:

listening to teacher **working quietly** **talking and working in a group**

listening to teacher **working quietly** **talking and working in a group**



4) Do you like to talk through your work with your group in class: yes/no

Explain your answer

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5) What is the best/worst thing about groupwork?

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6) Describe what would be an ideal **learning** lesson routine for you:

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7) If there is anything you want to add, write it here:

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Appendix XI – TIMSS – additional analyses

4.4.3 Do students feel confident in science?

The 2015 Trends in International Mathematics and Science Study, (TIMSS), statistics on student confidence levels in science are represented below, (Figure 4.4.8).

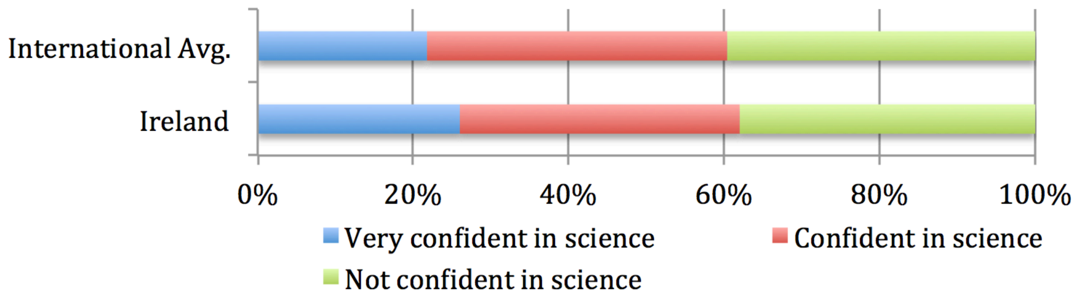

Figure 4.4.8 The International average and Irish distribution of responses from the 2015 TIMSS statements concerning whether students feel confident in science drawn from data retrieved from https://timssandpirls.bc.edu

None of the statements in the TIMSS 2015 or 2019 surveys actually use the word 'confident' and as such statements 23c from 2015 and 21c from 2019, which ask students to "Agree a lot", "Agree a little", "Disagree a little" or "Disagree a lot" with "Science is not one of my strengths", and 23g and 21g from the same years which presented students with "Science is harder for me than any other subject" have been selected for comparison with the TIMSS reports.

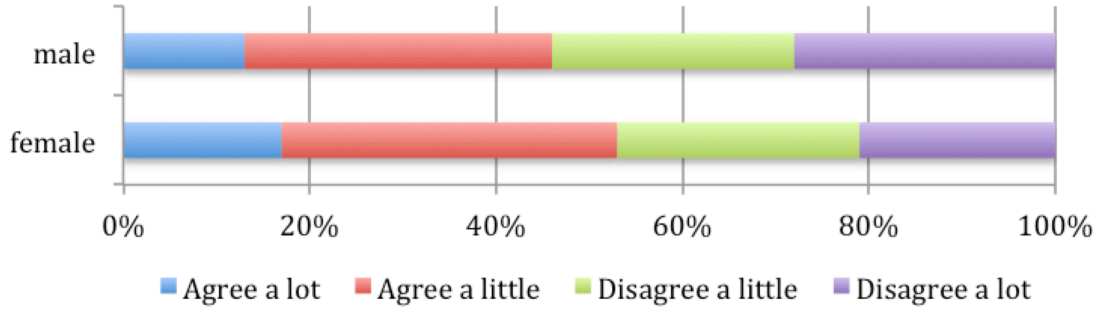

Figure 4.4.9 The responses to the 2015 TIMSS statement 23c “Science is not one of my strengths” separated by gender for second year students, (n=148)

There is a marked difference between the sixty-two percent national average of confident students, shown in Figure 4.4.8, and the fifty-one percent of students from this study who regarded science as one of their strengths, (Figure 4.4.9); although admittedly students might well feel confident in science whilst not regarding it as a strength.

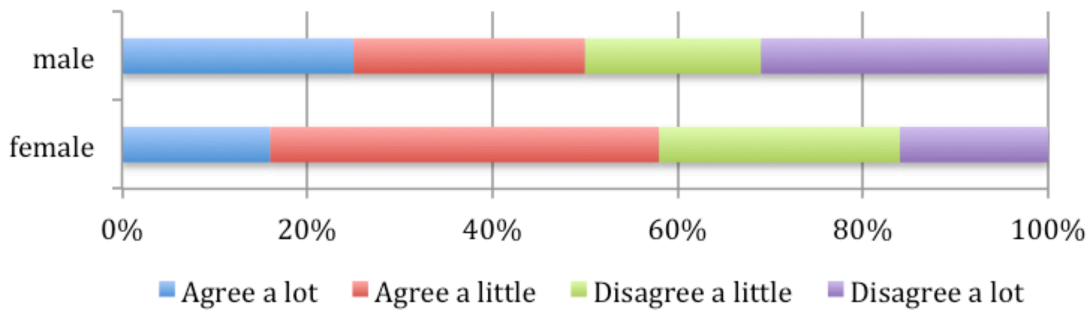

Figure 4.4.10 The responses to the 2015 TIMSS statement 23c “Science is not one of my strengths” separated by gender for second year students, (n=51), prior to implementation of student action cycles (SACs)

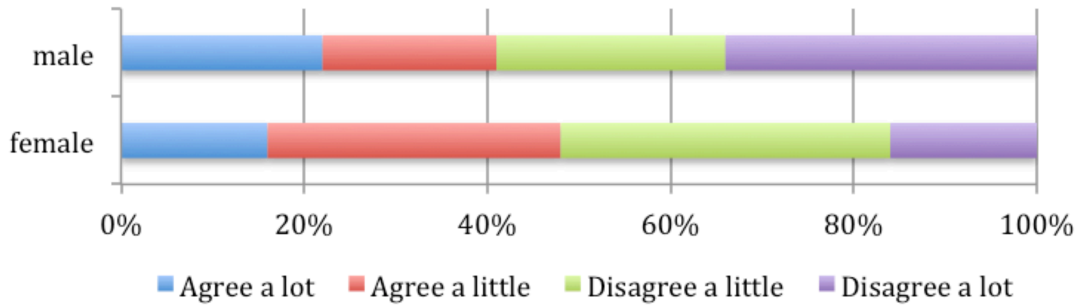

Figure 4.4.11 The responses to the 2015 TIMSS statement 23c "Science is not one of my strengths" separated by gender for second year students, (n=51), after implementation of student action cycles (SACs)

A comparison of Figures 4.4.10 and 4.4.11, shows a greater proportion of students regarded science as one of their strengths after using SACs than beforehand, (p=0.008, Wilcoxon Test, Z=2.646). While 46% of students in total stated that they agreed "a lot" or "a little" pre-implementation, this rose to 55% afterwards although this change in attitude was found to be relatively weak, (r=0.370).

The 2018 data set of second year students, (n=158), showed a similar distribution of to those from 2015 for the same statement, (Figure 4.4.12).

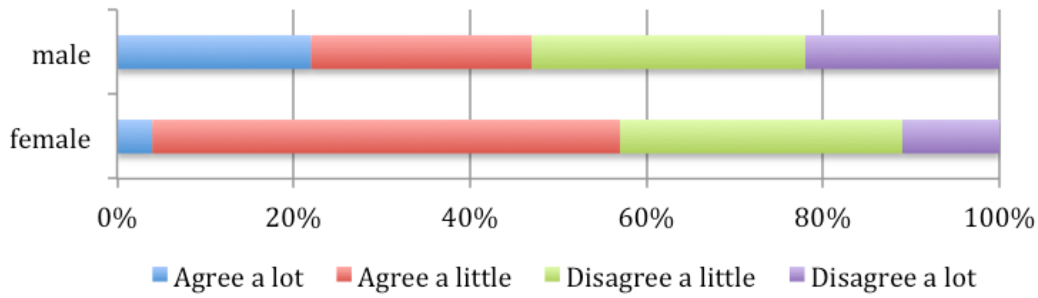

Figure 4.4.12 The responses to the 2019 TIMSS statement 21c "Science is not one of my strengths" separated by gender for second year students, (n=158).

The pre- and post-intervention distribution of responses for the sample group are shown below, (Figures 4.4.13 and 4.4.14).

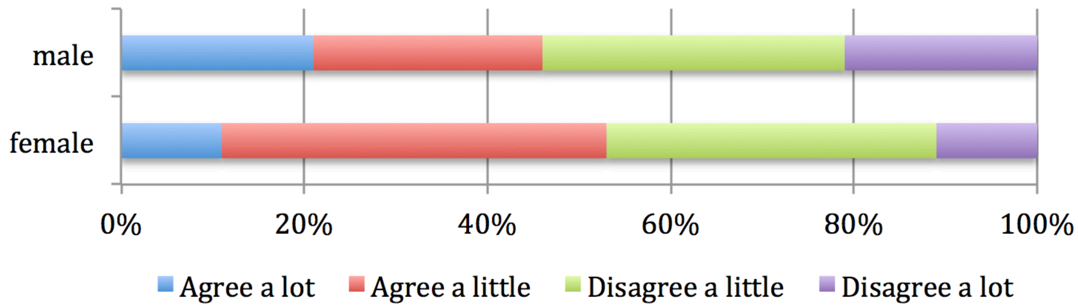

Figure 4.4.13 The responses to the 2019 TIMSS statement 21c "Science is not one of my strengths" separated by gender for second year students, (n=47) prior to implementation of student action cycles (SACs)

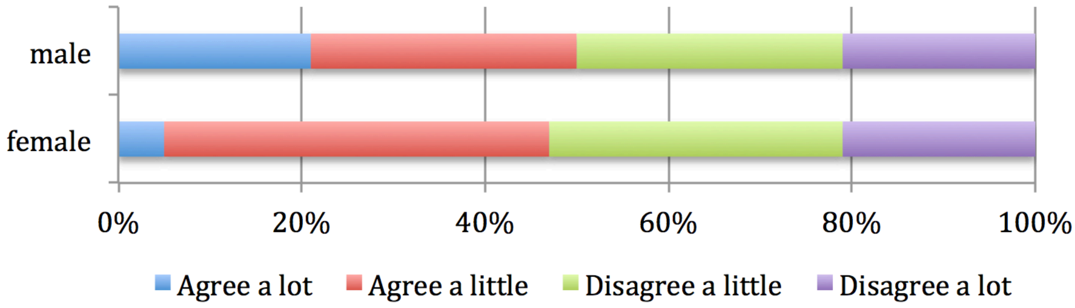

Figure 4.4.14 The responses to the 2019 TIMSS statement 21c "Science is not one of my strengths" separated by gender for second year students, (n=47), after implementation of student action cycles (SACs)

Although there are minor differences in the percentage of students identifying with the various attitude categories, no evidence can be found that these changes arose from the use of SACs, (p=0.180).

Student perceptions around the difficulty of the subject in comparison to others was assessed through the statement, "Science is harder for me than any other subject". Again, the statement's relation to confidence in science is by inference.

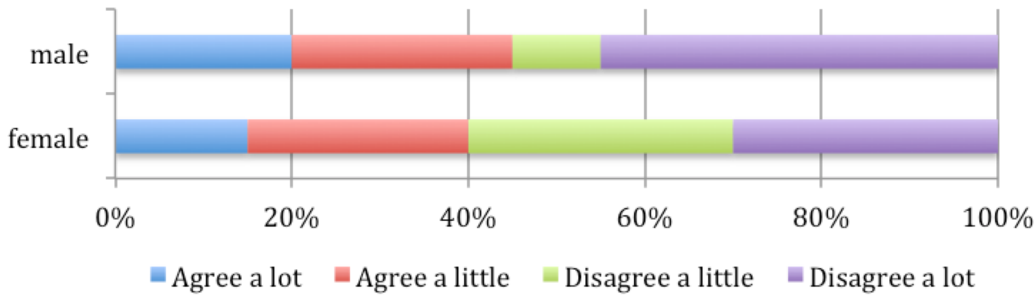

Figure 4.4.15 The responses to the 2015 TIMSS statement 23g "Science is harder for me than any other subject" separated by gender for second year students, (n=148).

The distribution of responses to the statement “Science is harder for me than any other subject” for the 2015 sample group, pre- and post-intervention, are shown below, (Figures 4.4.16 and 4.4.17).

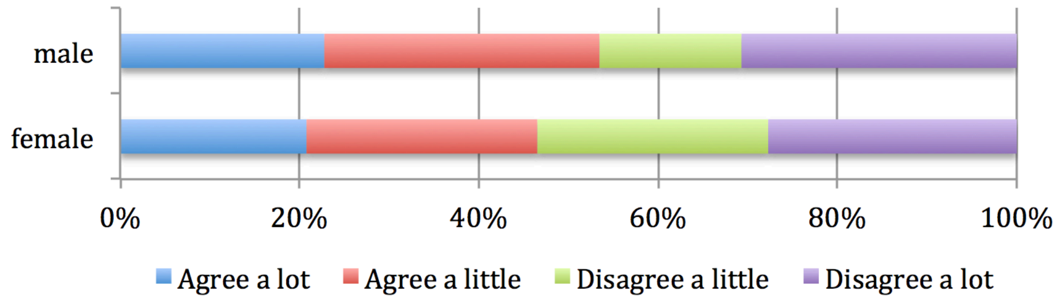

Figure 4.4.16 The responses to the 2015 TIMSS statement 23g “Science is harder for me than any other subject” separated by gender for second year students, (n=51) prior to implementation of student action cycles (SACs)

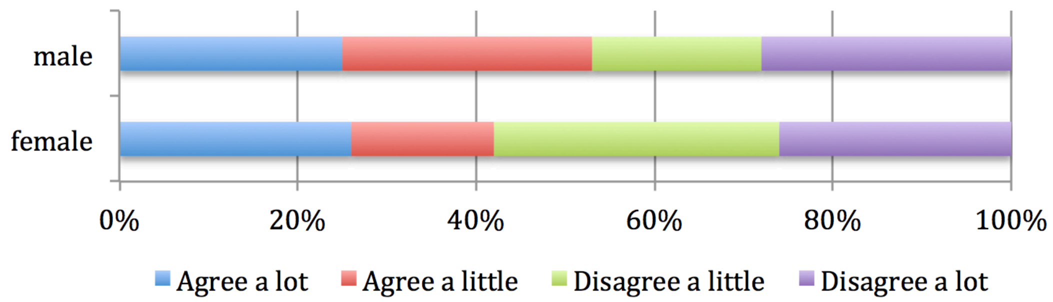

Figure 4.3.17 The responses to the 2015 TIMSS statement 23g “Science is harder for me than any other subject” separated by gender for second year students, (n=51), after implementation of student action cycles, (SACs).

Minor differences are visible between the pre- and post-intervention results but no evidence can be found that these changes arose from the use of SACs, (p=0.317).

When students were faced with the same statement in 2018, after the introduction of the new science specification, a very different result was observed as illustrated in

Figure 4.4.18 below; the 58% of students who disagreed a little or a lot that science was harder than other subjects in 2015 had increased to 86% percent.

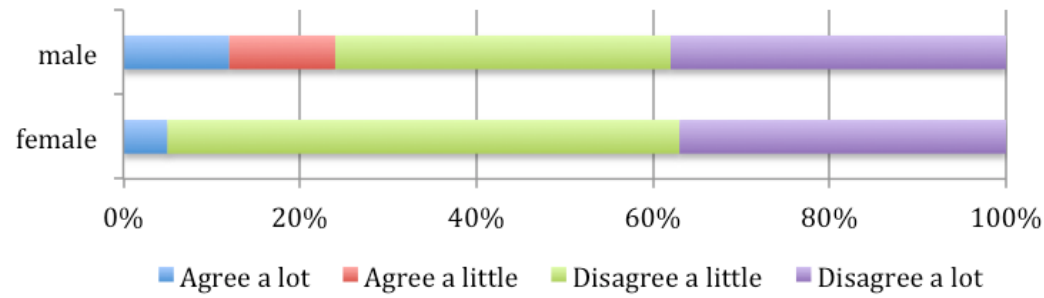

Figure 4.4.18 The responses to the 2019 TIMSS statement 21g "Science is harder for me than any other subject" separated by gender for second year students, (n=158).

The distribution of responses to the statement "Science is harder for me than any other subject" for the 2018 sample group, pre- and post-intervention, follow.

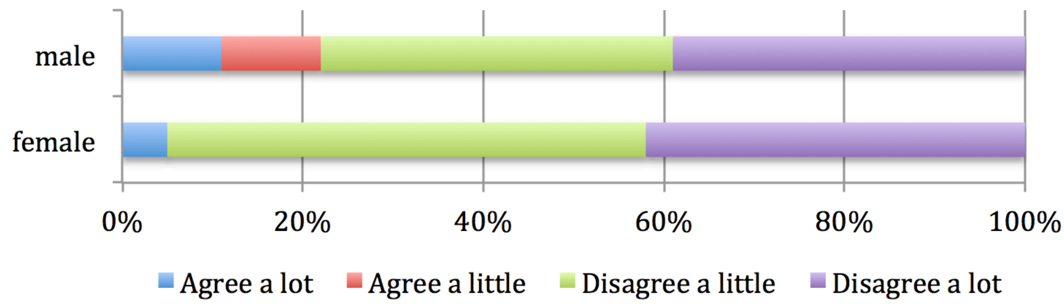

Figure 4.4.19 The responses to the 2019 TIMSS statement 21g "Science is harder for me than any other subject" separated by gender for second year students, (n=47) prior to implementation of student action cycles (SACs)

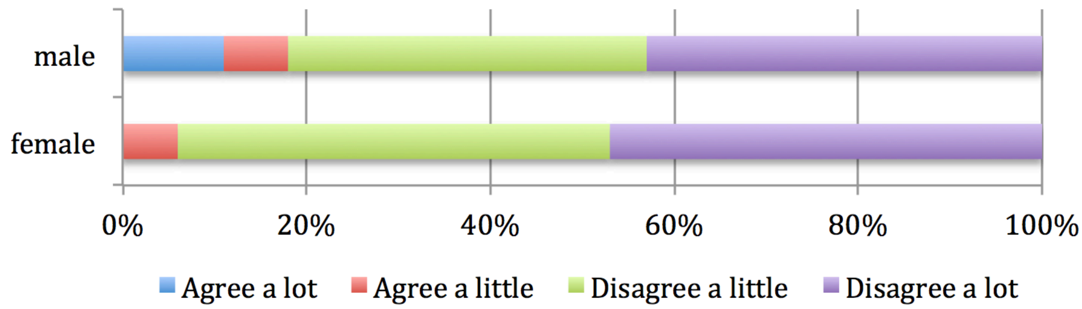

Figure 4.4.20 The responses to the 2019 TIMSS statement 21g "Science is harder for me than any other subject" separated by gender for second year students, (n=47) after implementation of student action cycles (SACs)

A comparison of Figures 4.4.19 and 4.4.20, shows that a greater proportion of students disagreed that science is harder than their other subjects after using SACs than beforehand, (p=0.046, Wilcoxon Test, Z=2.00). While 86% of students in total stated that they disagreed "a lot" or "a little" pre-implementation, this had risen to 88% afterwards although this change in attitude was found to be relatively weak, (r=0.292).

4.4.4 Do students value science as a subject?

As with student perceptions of confidence, (section 4.3.2), there are no specific statements in either the 2015 or 2019 Trends in International Mathematics and Science Study, (TIMSS), questionnaires that directly ask students whether they value science as a subject. A representation of the 2015 TIMMS results, covered by the heading, “Students Value Science”, and addressing the responses to all nine TIMSS statements in that category is shown below, (Figure 4.4.21).

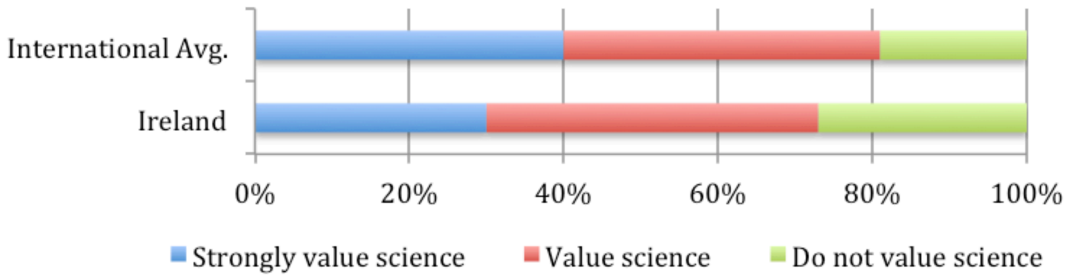

Figure 4.4.21 The International average and Irish distribution of responses from the 2015 TIMSS statements concerning whether students value science drawn from data retrieved from https://timssandpirls.bc.edu

Two statements were taken from the 2015 and 2019 TIMSS surveys for comparison. Statements 24a from 2015 and 22a from 2019 ask students to “Agree a lot”, “Agree a little”, “Disagree a little” or “Disagree a lot” with, “I think learning science will help me in my daily life”, and statements 24e and 22e, from the same years, present students with “I would like a job that involves using science”.

The 2015 and 2018 year group responses as to whether students are of the opinion that learning science will help them in their daily life are displayed in Figures 4.4.22 and 4.4.23 that follow.

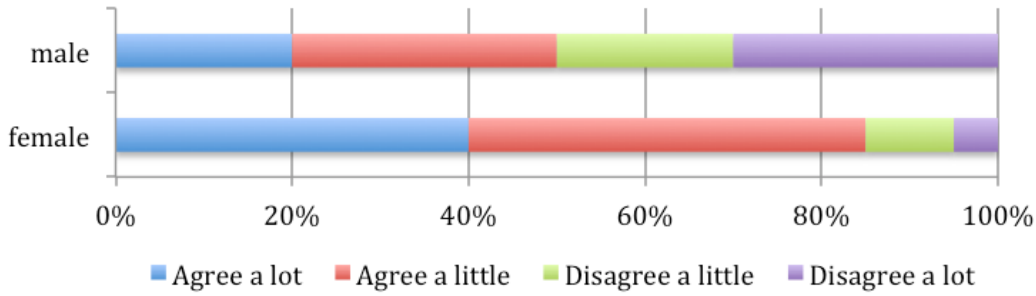

Figure 4.4.22 The responses to the 2015 TIMSS statement 24a "I think learning science will help me in my daily life" separated by gender for second year students, (n=148).

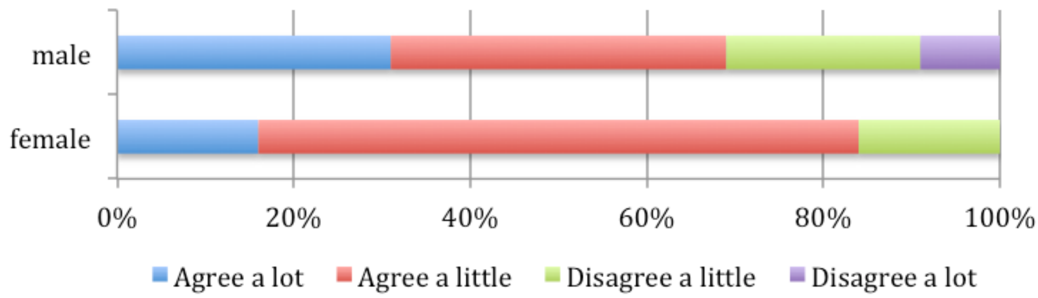

Figure 4.4.23 The responses to the 2019 TIMSS statement 22a "I think learning science will help me in my daily life" separated by gender for second year students, (n=158).

The distribution of responses to the same statement for the 2015 sample group, pre- and post-intervention, are shown in Figures 4.4.24 and 4.4.25.

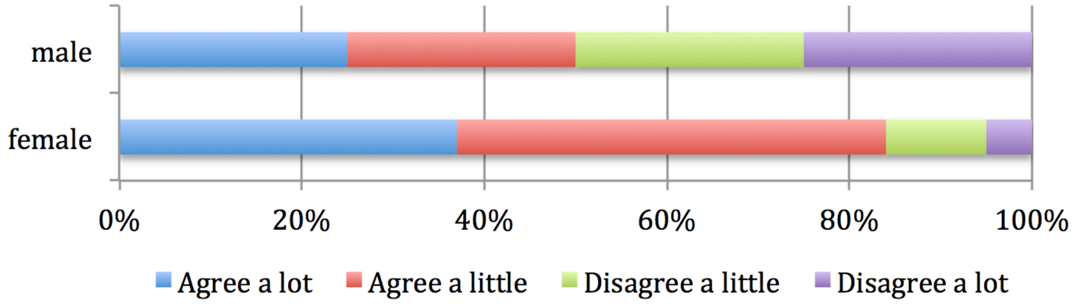

Figure 4.4.24 The responses to the 2015 TIMSS statement 24a "I think learning science will help me in my daily life" separated by gender for second year students, (n=51) prior to implementation of student action cycles (SACs)

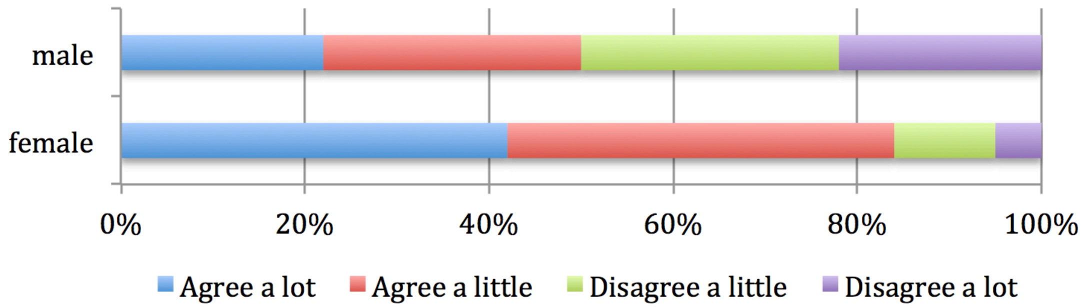

Figure 4.4.25 The responses to the 2015 TIMSS statement 24a "I think learning science will help me in my daily life" separated by gender for second year students, (n=51) after implementation of student action cycles (SACs)

Minor differences are visible between the pre- and post-intervention results but no evidence can be found that these changes arose from the use of SACs, (p=0.564).

The distribution of responses to the statement "I think learning science will help me in my daily life" for the 2018 sample group, pre- and post-intervention, follow.

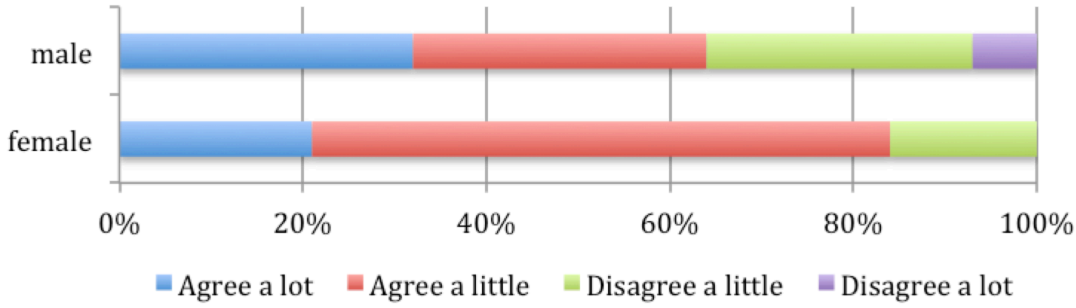

Figure 4.4.26 The responses to the 2019 TIMSS statement 22a "I think learning science will help me in my daily life" separated by gender for second year students, (n=47) prior to implementation of student action cycles (SACs)

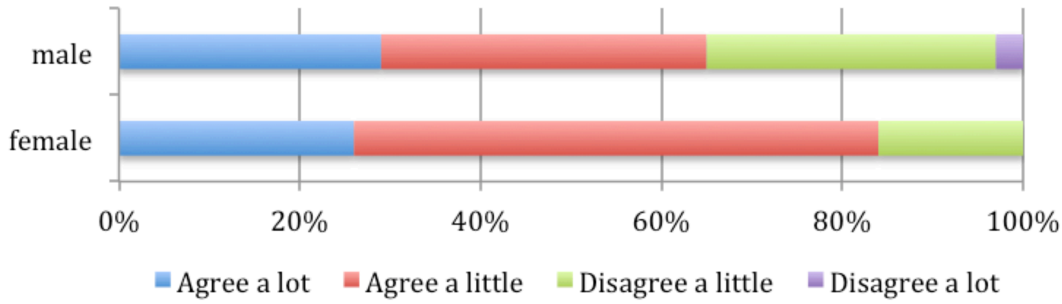

Figure 4.4.27 The responses to the 2019 TIMSS statement 22a "I think learning science will help me in my daily life" separated by gender for second year students, (n=47) after implementation of student action cycles, (SACs).

Very minor differences are visible between the pre- and post-intervention results but no evidence can be found that these changes arose from the use of SACs, (p=0.317).

The 2015 and 2018 year group responses as to whether students would like employment with a scientific component are displayed in Figures 4.4.28 and 4.4.29.

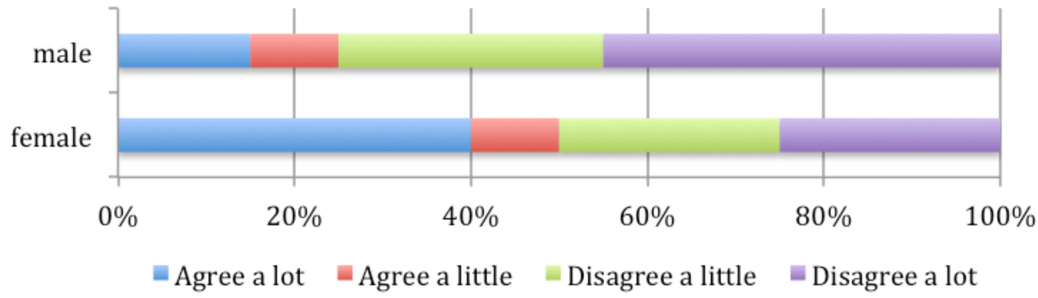

Figure 4.4.28 The responses to the 2015 TIMSS statement 24e “I would like a job that involves using science” separated by gender for second year students, (n=148).

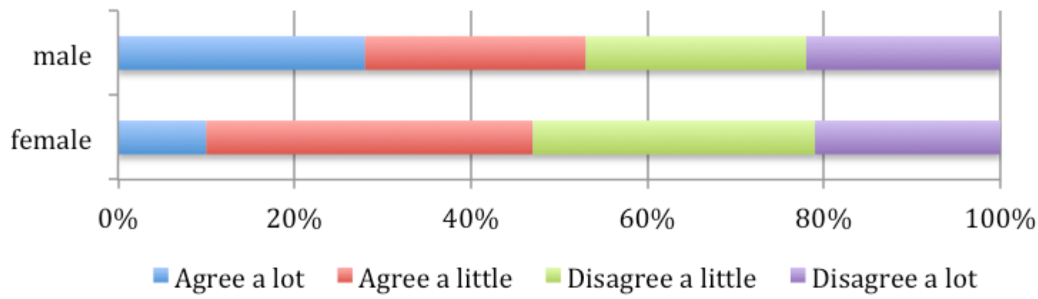

Figure 4.3.29 The responses to the 2019 TIMSS statement 22e “I would like a job that involves using science” separated by gender for second year students, (n=158).

Whether or not SACs had an effect on the distribution of students who wanted a job with science can be seen in the graphs, (figures 4.4.30 and 4.4.31), pre- and post-intervention, for the 2018 cohort.

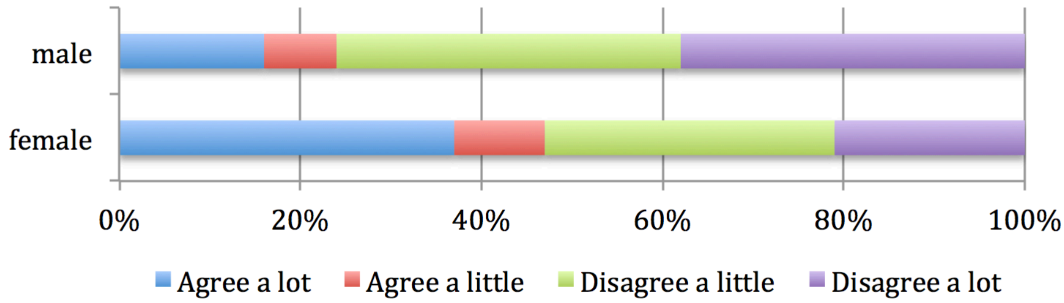

Figure 4.4.30 The responses to the 2015 TIMSS statement 24e "I would like a job that involves using science" separated by gender for second year students, (n=51) prior to implementation of student action cycles (SACs)

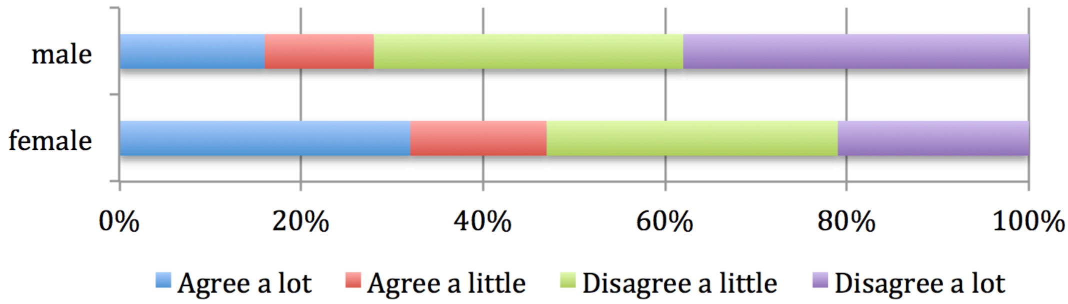

Figure 4.4.31 The responses to the 2015 TIMSS statement 24e "I would like a job that involves using science" separated by gender for second year students, (n=51) after implementation of student action cycles (SACs)

Minor differences are visible between the pre- and post-intervention results but no evidence can be found that these changes arose from the use of SACs, (p=0.564).

The same analysis was performed on the 2018 pre- and post-intervention responses, as displayed below, (Figures 4.4.32 and 4.4.33).

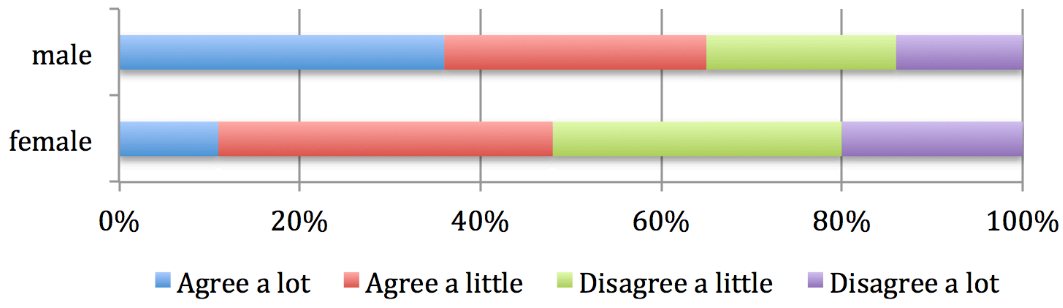

Figure 4.4.32 The responses to the 2019 TIMSS statement 22e "I would like a job that involves using science" separated by gender for second year students, (n=47) prior to implementation of student action cycles (SACs)

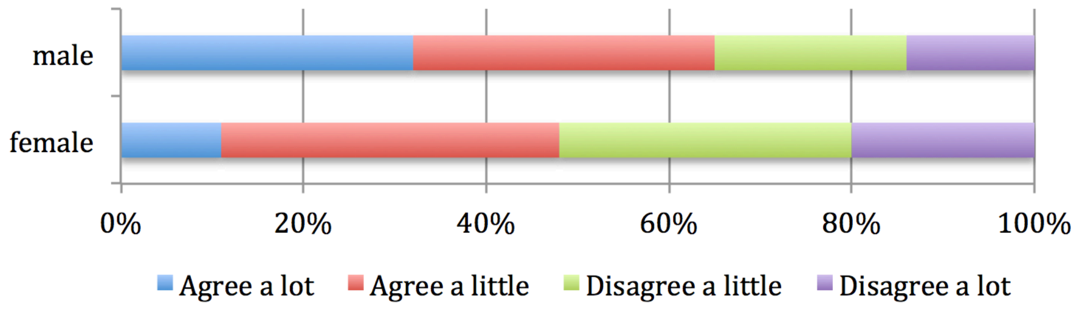

Figure 4.4.33 The responses to the 2019 TIMSS statement 22e "I would like a job that involves using science" separated by gender for second year students, (n=47) after implementation of student action cycles, (SACs).

Very minor differences are visible between the pre- and post-intervention results but no evidence can be found that these changes arose from the use of SACs, (p=0.317).

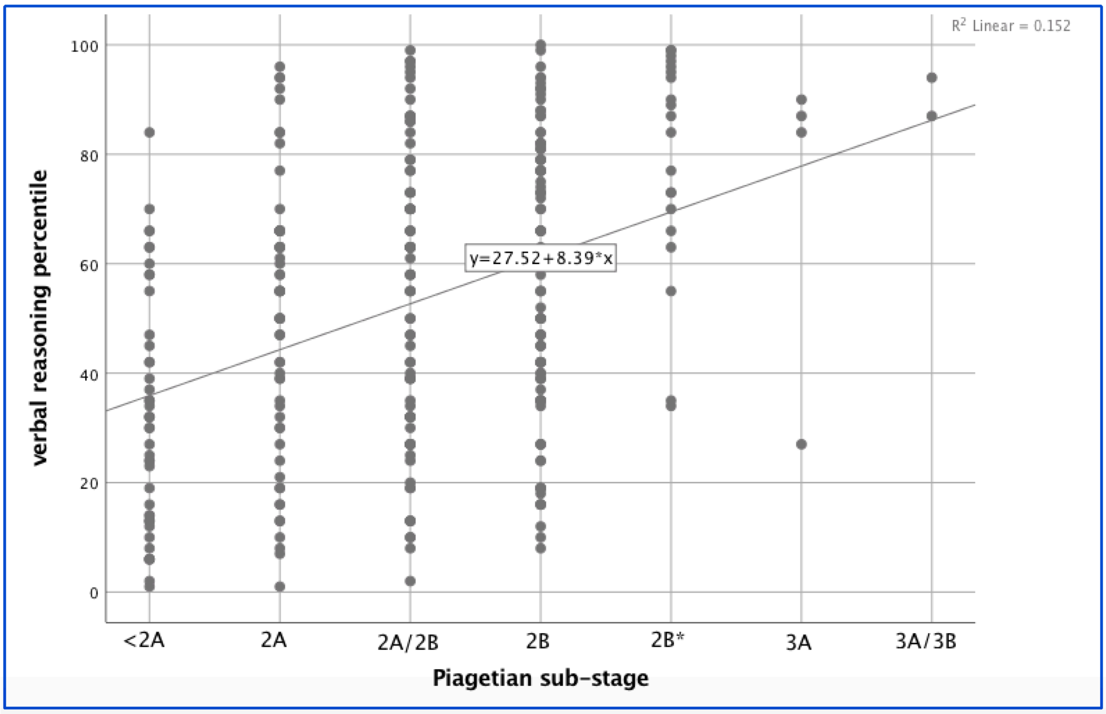

Figure 4.7.2 The correlation between the Piagetian sub-stages of students, as established through the application of the "*Volume and heaviness*" science reasoning task, and the verbal reasoning percentiles determined through the application of the Drumcondra or CAT4 tests, (n=310)

A fairly weak but positive correlation was observed between the Piagetian sub-stage and the verbal reasoning percentiles, (r_p=0.390, p<0.001).

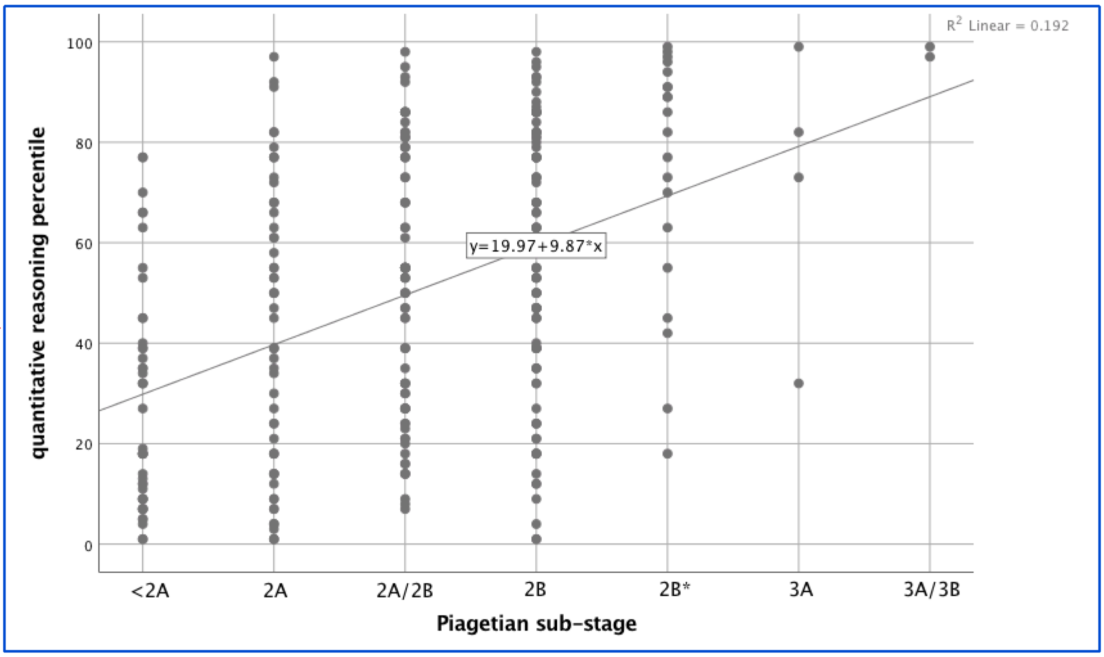

Figure 4.7.3 The correlation between the Piagetian sub-stages of students, as established through the application of the "*Volume and heaviness*" science reasoning task, and the quantitative reasoning percentiles determined through the application of the Drumcondra or CAT4 tests (n=310)

A moderate and positive correlation was observed between the Piagetian sub-stage and the quantitative reasoning percentiles, (r_p=0.439, $p<0.001$).

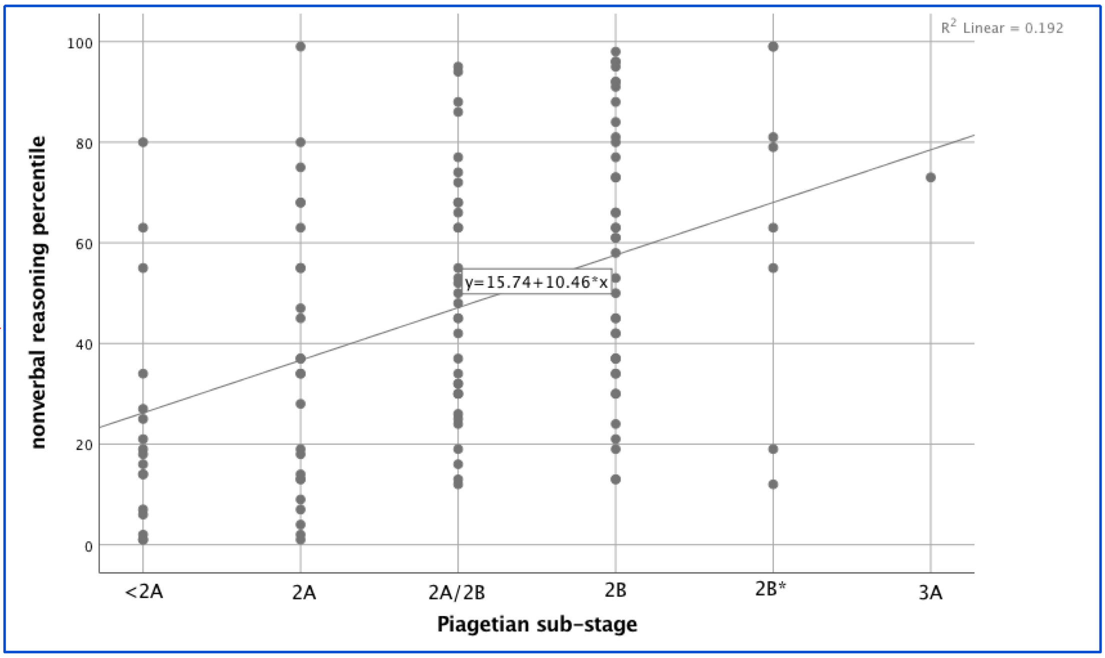

Figure 4.7.4 The correlation between the Piagetian sub-stages of students, as established through the application of the "*Volume and heaviness*" science reasoning task, and the nonverbal reasoning percentiles determined through the application of the CAT4 tests (n=124)

A moderate and positive correlation was observed between the Piagetian sub-stage and the nonverbal reasoning percentiles, (r_p=0.438, p<0.001).

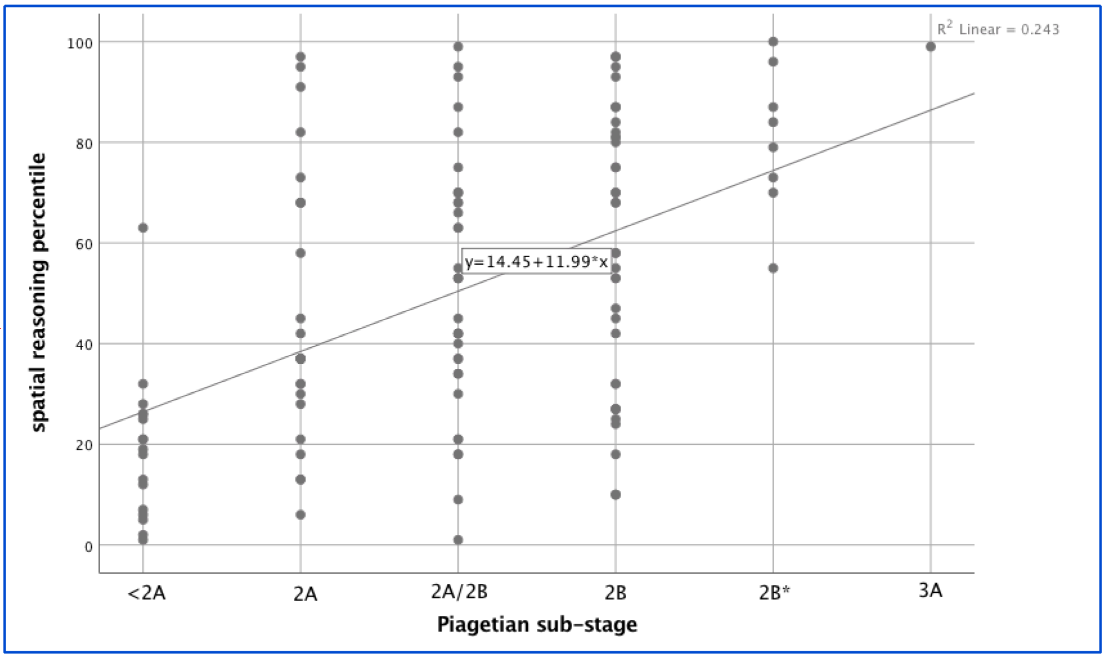

Figure 4.7.5 The correlation between the Piagetian sub-stages of students, as established through the application of the "*Volume and heaviness*" science reasoning task, and the spatial reasoning percentiles determined through the application of the CAT4 tests (n=124)

Appendix XIII – SRTs compared to junior certificate results

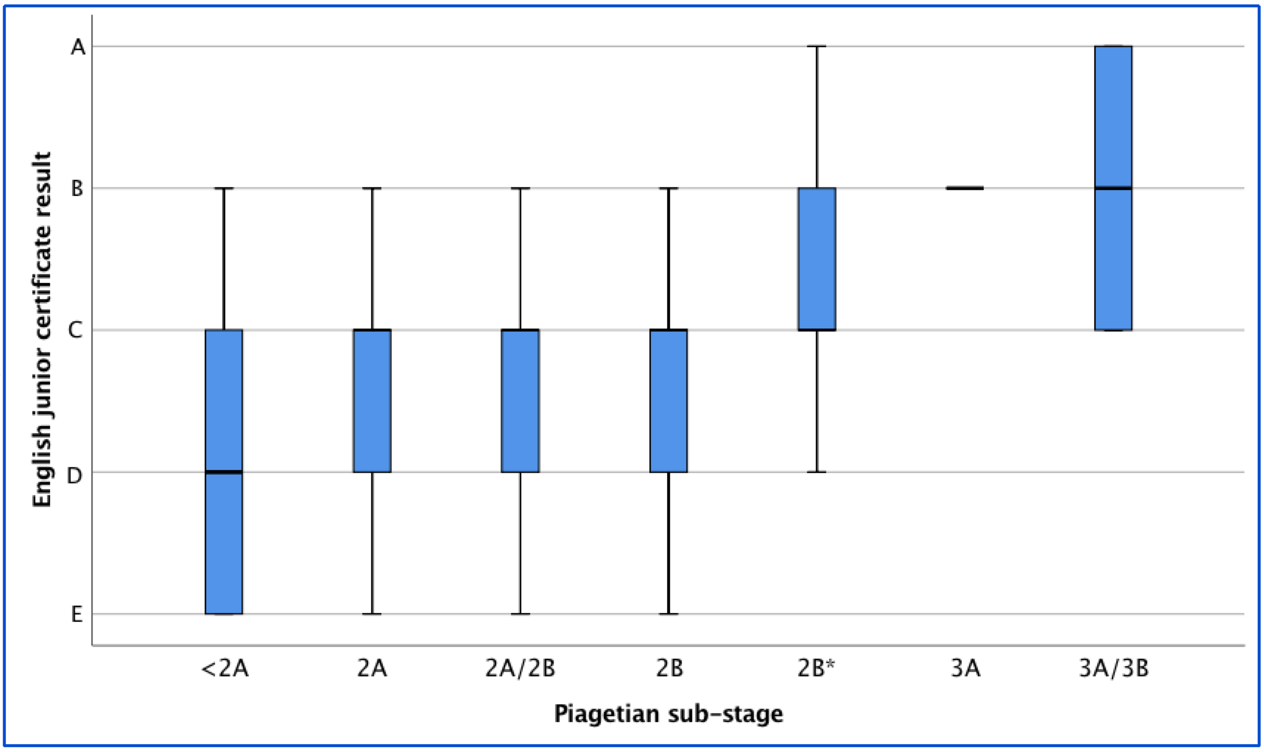

Figure 4.7.6 The correlation between the Piagetian sub-stages of students, as established through the application of the "*Volume and heaviness*" science reasoning task, and their performance in the junior certificate English examination, (n=305)

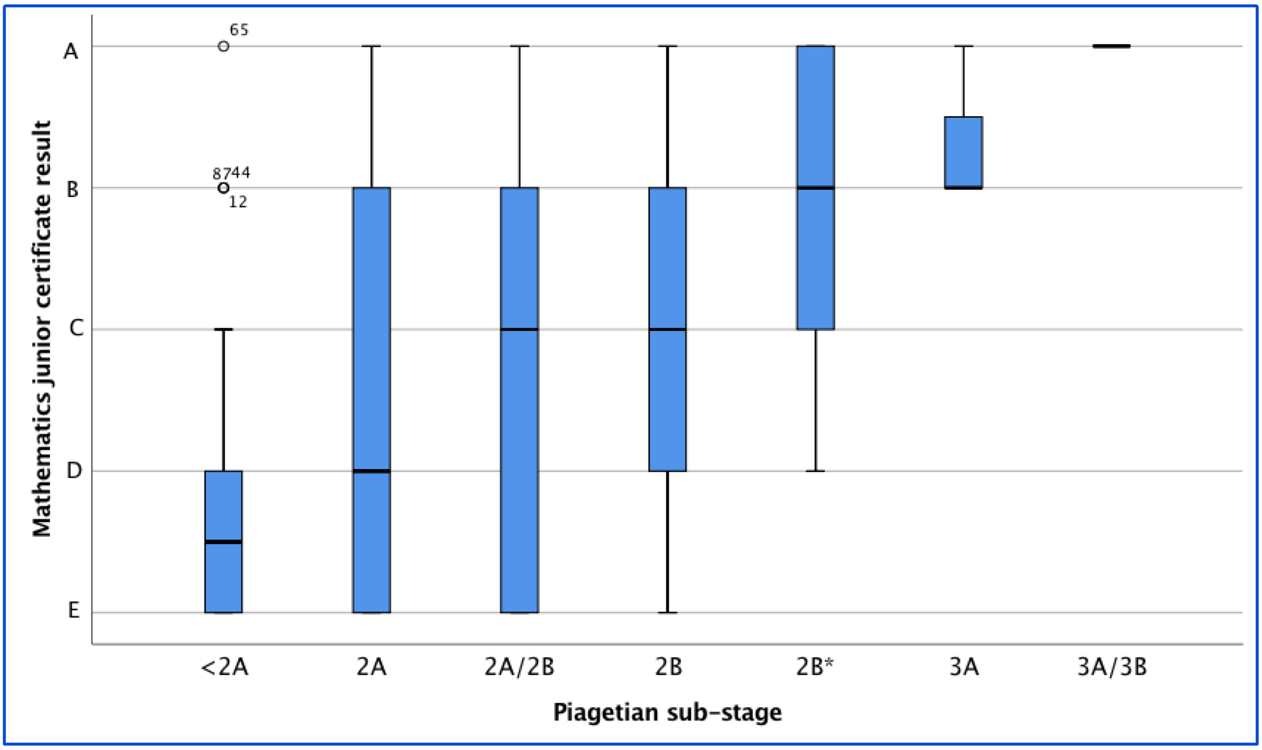

Figure 4.7.7 The correlation between the Piagetian sub-stages of students, as established through the application of the "*Volume and heaviness*" science reasoning task, and their performance in the junior certificate mathematics examination, (n=305)

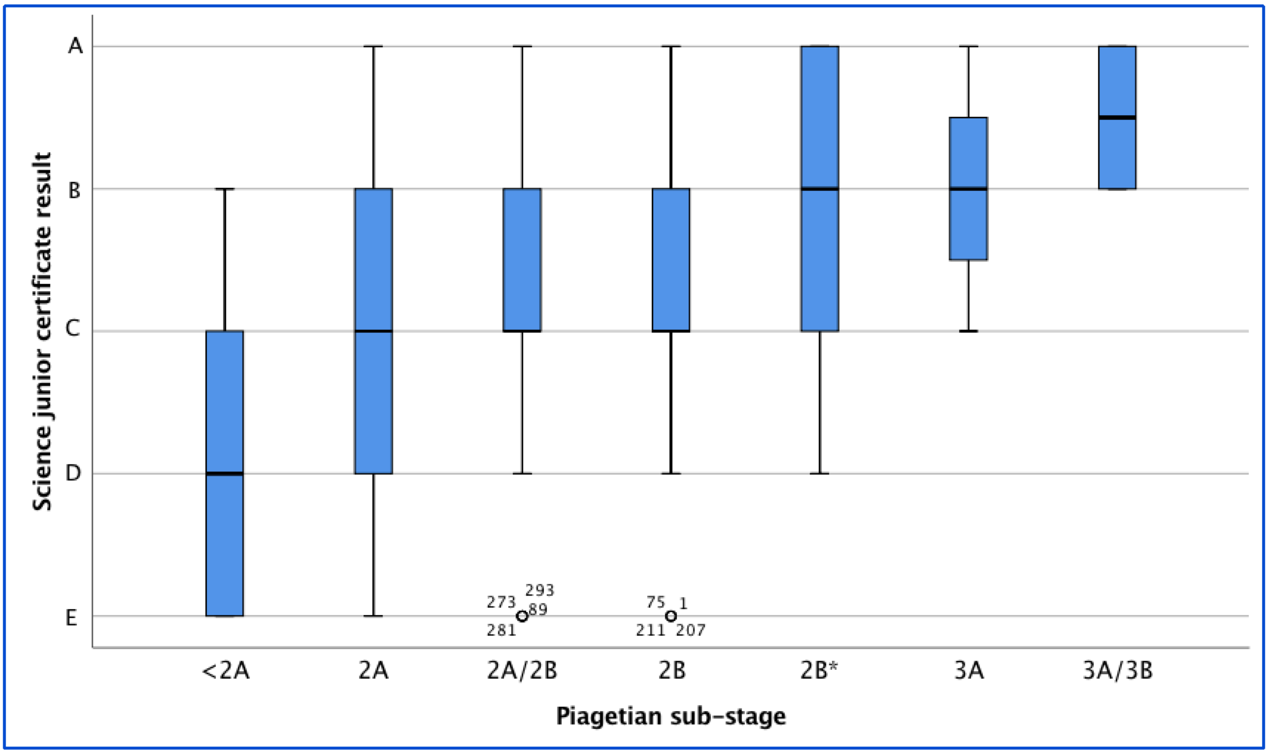

Figure 4.7.8 The correlation between the Piagetian sub-stages of students, as established through the application of the "*Volume and heaviness*" science reasoning task, and their performance in the junior certificate science examination, (n=305)