‘What are you doing and how are you going to achieve it?’: Shifting Focus to Skill Development in Year 11 Chemistry

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Bachelor of Arts and Master of Teaching

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Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Abstract

In the 21st Century, higher order skills and capabilities are the most desirable qualities to industry, supplanting content knowledge as the most critical quality. Furthermore, teachers are always looking at ways to increase student engagement. The Models of Engaged Learning and Teaching (MELT) framework was developed by Willison & O'Regan in order to address these issues (2007; 2018). MELT has been shown to increase student engagement and explicitly develop the skills students required for higher education and employment in industry (McGowan, 2018; Willison, 2018;

Willison & O'Regan, 2007). In this study, MELT was implemented in a secondary school in suburban, Adelaide, South Australia. Employing the participant observer methodology, a pre-service teacher undertaking the Master of Teaching program at the University of Adelaide, attended seven, year 11 chemistry lessons and produced a series of vignettes that described student interactions. These were then thematically analysed in order to determine the nature and extent of student demonstrated engagement with and about the MELT framework, and the nature of student classroom interaction with relation to MELT facets and autonomy when MELT is not used explicitly. Furthermore, the study analysed the data in relation to the concept of metacognition, flow and visible thinking routines (Csikszentmihalyi, 1991; Flavell, 1979; Ritchhart & Perkins, 2008). The study illustrated that each of the MELT facets was needed by year 11 secondary school students in the course of each chemistry lesson, and concluded that MELT may support skill development in this context. Furthermore, the study asserts that student engagement and learning may be improved if students and teachers focus on skill development rather than results. Finally, the study recommends that further research be undertaken in relation to MELT's potential in secondary schools, and suggests that MELT include more emphasis on the affective domain.

List of abbreviations

MELT	Models of Engaged Learning and Teaching
SACE	South Australian Certificate of Education
CASE	Cognitive Acceleration through Science Education
RSP	Research Skill Pentagon
RSD	Research Skill Development
DfE	Department for Education

Contents

Chapter 1: Introduction

1.1 Introduction

In the 21st Century, higher order skills and capabilities are the most desirable qualities to industry, supplanting content knowledge as the most critical quality. The unrelenting knowledge boom and its increased accessibility due to technology continually subtracts from the value of memorising content knowledge (Goldie, 2016; Siemens, 2005). Furthermore, truths now frequently change. Old knowledge becomes increasingly obsolete due to the establishment of new contexts, information and research: 'The right answer now might be wrong tomorrow' (Siemens 2005, p. 4). Therefore, the ability to use higher order thinking skills in order to determine what to learn, what to connect, and which ideas are most useful is increasingly advantageous (Lucas & Smith, 2018; Siemens, 2005; Trilling & Fadel, 2009). However, ensuring students develop cognitive skills and capabilities that can be transferred to external contexts remains a challenge. Secondary school graduates are completing their studies without having developed 'the skills employers are looking for' (Lucas & Smith, 2018, p. 4). Perhaps it is time for Australian primary and secondary educators to shift their focus from *what* is being studied, to *how* students learn and develop their skills and capabilities.

These observations illustrate that teachers in secondary schools exist in an era where the skill development of their students, particularly within the cognitive and affective domains, is now paramount. This challenge has been addressed by mandating skills-focused subjects within the curriculum. The South Australian Certificate of Education

(SACE) board prescribed the ‘Research Project’ for year 11 secondary students, which is analogous to the International Bachelorette’s ‘Personal Project’ (International-Bachelorette, SACE). These subjects promise to help students develop skills for ‘further study and work’ and commit students to ‘lifelong learning’ (International-Bachelorette, SACE). However, despite their intent, ‘parents and school staff want the Research Project scrapped’ (P. 1), which reflects the reality that secondary students are not in fact reaping the proposed benefits - an issue which permeates primary education systems, too (Williams, 2018).

The late inclusion of research subjects in secondary education illustrate that skill development is neglected in the early years. This systematic delay has failed to deliver results (Lucas & Smith, 2018). Students do not necessarily develop ‘higher-order inquiry skills’ as a result of these subjects because an individual can can do research without developing research skills (Kardash, 2000; Torres, 2018). Furthermore, students prefer to ‘slowly’ (Willison, 2018, p. 3) develop their skills (Gresty, Heffernan, Pan, & Edward-Jones, 2015). Expecting them to rapidly improve as a result of compacted research subjects seems unrealistic

While students’ difficulties in developing skills and capabilities might be partly explained by the belated and limited exposure to skill development, the way teachers are directed may have a more significant impact. Teachers are often focused on results, while placing little value on ‘the thinking processes and understanding developed in obtaining them’ (Torres 2018, p. 3). In higher education, educators place ‘little emphasis on the development of the multifaceted skill development’ (McGowan, 2018 p. 6), which is reflected in primary and secondary education contexts, too (Lucas

& Smith, 2018). The current fixation on results, rather than skill development, signifies that teachers and students need more support in understanding and emphasising the necessary 21st century skills.

In order to focus on skill development, a clear articulation of the skills students demonstrate through their education is necessary. Just as the 3Rs describes the 'core skills' (Kivunja 2014, p. 85) students develop through schooling, frameworks have emerged that guide educators and students in targeting deliberate, multifaceted skill development (Lucas & Smith, 2018; Ware, 2018). For example, the 'Research Skill Development' (Willison and O'Regan 2007, p. 393) framework, which has since been adapted to 'Models of Engaged Learning and Teaching' (MELT) (Willison 2018, p. 35), has proven useful in guiding students' skill development in higher education contexts (Bandaranaike, 2018; McGowan, 2018; Torres, 2018; Willison, 2018; Willison & O'Regan, 2007). MELT explicitly articulates the various skills and capabilities students develop through their education, and can be adapted to a multitude of contexts (Willison, 2018; Willison & O'Regan, 2007). However, this model has seen limited application in secondary education (Willison 2018). If its success in tertiary education can be replicated in secondary education, it will prove useful for both students and teachers guiding deliberate skill development. Therefore, its potential in a secondary education context needs to be explored.

1.2 Aims and objectives

The purpose of this research was to uncover insights into what skills were demonstrated within a South Australian, Year 11 Chemistry classroom in relation to

MELT, and to observe and analyse how students interacted with MELT when it is made explicit.

While this research was not comprehensive enough to measure the efficacy of MELT in improving skill development, by observing and recording students' classroom interactions, their explicit and implicit engagement with MELT could be analysed, and improvements to the framework were suggested in the context of secondary education.

1.3 Research questions

What is the nature and extent of student demonstrated engagement with and about the MELT framework?

When MELT is not used explicitly, what is the nature of student classroom interaction with relation to MELT facets and autonomy?

Chapter 2: Literature review

2.1 Metacognition and the development of metacognitive frameworks

Decades ago, Flavel termed the knowledge and monitoring of the cognitive and affective domains as ‘metacognition’ (1979). Metacognition includes knowledge of self, knowledge of task, and knowledge of strategy (Bannister-Tyrrell & Clary, 2017; Flavell, 1979). Knowledge of self relates to the affective domain, which cover emotions and motivations, while knowledge of strategy relates to the cognitive domain, which covers skills such as critical and creative thinking (Bannister-Tyrrell & Clary, 2017; Flavell, 1979). Students often have sufficient knowledge of task, but their knowledge and regulation of self and strategy are limited (Bannister-Tyrrell & Clary, 2017; Tarricone, 2011). Since the conception of the term metacognition, a multitude of metacognitive frameworks have emerged which guide educators in implementing metacognition in the classroom (Dajani, 2016; Lucas & Smith, 2018)).

Teaching metacognition can increase ‘effective student learning and achievement’ (DEECD, 2010, p. 2). Understanding and regulating the cognitive and affective domains can encourage students to think more deliberately about *how* they learn (Bannister-Tyrrell & Clary, 2017)). Nevertheless, in order to better understand how metacognitive frameworks such as MELT might encourage metacognition in the classroom, it is important to uncover why teaching metacognition is necessary in the first place.

Students increasingly rely on technology to do their thinking for them (Bannister-Tyrrell & Clary, 2017; Siemens, 2005). For example, students rely heavily on search engines to find knowledge, offloading their cognitive processes to the technology ((Bannister-Tyrrell & Clary, 2017; Siemens, 2005)). Therefore, they lose opportunities to exercise various cognitive skills. These lost opportunities can be mitigated if students intentionally exercise their cognitive abilities (Bannister-Tyrrell & Clary, 2017; Tarricone, 2011)). Moreover, they must develop new cognitive processes in order to take advantage of technology (Goldie, 2016).

The theory of connectivism helps explain why cognitive skill development is critical in the 21st Century (Siemens, 2005). Connectivism asserts that knowledge and learning is constructed and developed by networks and communities, therefore students need to learn how to manage the 'flow of information' (Siemens, 2005; AlDahdoug, 2017 p. 23-24). When a student makes too many connections in a network of information it can become too complex and their learning suffers (AlDahdouh, 2017). On the other hand, limited connections, for example, if a lesson is packed with lectures and textbooks, can inhibit information flow and learning, notwithstanding dense information intake increases the load on working memory (Oliver & Venville, 2017; Wieman, 2007). Over-connected students must be guided to consciously and deliberately engage and regulate their cognitive and affective domains in order to effectively prioritise and manage information (Deslauriers, Schelew, & Wieman, 2011; Oliver & Venville, 2017).

Since Flavel articulated the concept of metacognition, a multitude of research has followed and been promulgated within education, leading to the development of various frameworks (Flavell, 1979; Oliver & Venville, 2017). With a 'vocabulary to

describe' (Bannister-Tyrrell & Clary, 2017, p.71; Moseley et al., 2005) how students learn, teachers are better able to guide them through the metacognitive processes involved in critical thinking and analysing, which leads to improvements in learning and engagement (Deslauriers et al., 2011; Oliver & Venville, 2017). By practicing metacognition, students begin to strengthen their cognitive abilities such as reasoning, increasing their ability manage their learning (Oliver & Venville, 2017)). These skills and capabilities can then be transferred into contexts outside of school, while content knowledge is often redundant due to its dependence on particular contexts.

2.2 Engagement: Flow and student engagement.

Student engagement is critical to effecting teaching and learning. While students may be engaged due negative affective states driven by motivations such as the avoidance of failure, the most desirable type of engagement is a state known as flow, which characterises cognitive engagement and leads to deep learning (Csikszentmihalyi, 1991; D'Mello & Graesser, 2012; Oliver & Venville, 2017). The concept of flow was developed by Csikszentmihalyi in order to articulate the processes that lead to cognitive engagement (Csikszentmihalyi, 1991).

Flow is an affective-cognitive state where an individual is entirely absorbed in an activity or task to the extent that they become unconscious of anything that does not relate to it (Csikszentmihalyi, 1991; D'Mello & Graesser, 2012; Koehn, 2013; Rodríguez-Ardura & Meseguer-Artola, 2017). They lose a sense of time and self, and the experience is often reported as enjoyable (Harmat, Ørsted Andersen, Ullén, Wright, & Sadlo, 2016) Students who experience states of flow are likely to immerse

themselves in tasks despite there being no extrinsic motivation for completing them, and students' post-task behavioural and affective states become peaceable and pleasant (Harmat et al., 2016).

The need to feel competent appears to be the core driver of the flow state, which is described in Haslow's hierarchy of needs as esteem (Harmat et al., 2016; Maslow, 1943; Moseley et al., 2005; Rodríguez-Ardura & Meseguer-Artola, 2017). In order for students to achieve this sense of competence, tasks need to meet these fundamental requirements:

- The task must have clear goals so that student know exactly what they are working towards and why (Rodríguez-Ardura & Meseguer-Artola, 2017).
- Students must receive immediate feedback as a result of completing the task, or from teachers or peers (Rodríguez-Ardura & Meseguer-Artola, 2017).
- Students require a sense of control (Rodríguez-Ardura & Meseguer-Artola, 2017). When a student feels that control has been taken away, they are likely to reject the task (Rodríguez-Ardura & Meseguer-Artola, 2017). When students are empowered with a sense of control, they are more likely to apply their initiative (Rodríguez-Ardura & Meseguer-Artola, 2017).
- Students need to feel that the task is demanding, while being confident that they can complete it successfully (Harmat et al., 2016; Rodríguez-Ardura & Meseguer-Artola, 2017). If a task is too easy, how will students gain a sense of competence? If a task if too demanding, students will become frustrated or confused (D'Mello & Graesser, 2012).

In order to maximise students' cognitive skill development during flow, they require

challenges that will engage various cognitive abilities (D'Mello & Graesser, 2012; Rodríguez-Ardura & Meseguer-Artola, 2017). However, it is important for teachers to monitor the various affective states that students experience while completing tasks because they take place during cognitive processes and may signal engagement or disengagement (Barrett, 2009; D'Mello & Graesser, 2012).

When a student's state of flow is interrupted by an 'impasse' (D'Mello & Graesser, 2012, p. 145) - a problem or obstacle presented by the task - they enter a state of confusion. Students are then required to exercise their cognitive skills in order to overcome the impasse (D'Mello & Graesser, 2012). If the impasse is overcome, the student will continue the task and return to a state of flow. This process provides insights into why successful students feel a sense of competence and positive emotion. It is a result of cognitive engagement leading to the mastery over a task's inherent challenges (Barrett, 2009; D'Mello & Graesser, 2012).

However, if the impasse is not overcome the student will become frustrated (D'Mello & Graesser, 2012). If this occurs consistently within a task, the student will become bored and disengage from the task, and if this occurs frequently over a variety of tasks, students may begin to associate a sense of hopelessness with a particular subject or topic (D'Mello & Graesser, 2012). This process helps explain one of the potential causes of disengagement, and signifies that teachers should attempt to become cognisant of how their students are responding to tasks. When a student appears frustrated, it may signal that the task is too demanding, and that they need the teacher's support in in order to engage their cognitive capabilities (D'Mello & Graesser, 2012). With the teachers support, the student is more likely to re-engage in the task, successfully complete it, and ultimately gain a sense of competence.

2.3 Thinking Routines: Frameworks for cognitive engagement.

Flow may help explain why it is necessary for educators to increase cognitive engagement during tasks, however, engaging students' cognitive skills during lectures and less structured, formative work can be challenging. To meet this challenge, educators may benefit from employing another metacognitive framework: Visible thinking routines (Boix Mansilla, 2016; R. Ritchhart, Church, & Morrison, 2011). Visible thinking routines are simple sets of questions or prompts that encourage independent thought on topics or subjects (Ritchhart & Perkins, 2008; Wolberg & Goff, 2012). Through guided and deliberate thinking, students are encouraged to exercise their cognitive skills and capabilities. According to Ritchhart and Perkins, 'learning is a consequence of thinking', and the purpose of thinking routines is to 'make thinking visible' (Ritchhart & Perkins, 2008, p. 58), therefore making learning visible, and developing students' metacognition (2008). When students see the processes of learning and cognitive skill development, they develop better thinking practices (Ritchhart & Perkins, 2008; Wolberg & Goff, 2012).

Thinking routines do not rely on specific tasks, therefore they can balance content delivery with skill development. For example, the 'think/pair/share' routine can be utilised to help students generate thoughts and reflect on their thinking (Dyan, 2017). Employing this routine, a teacher might give students two minutes to think alone about a topic or subject upon which they have been lecturing (think), two minutes to share their thoughts with a partner (pair), and then ask students to share their thoughts with the class (share). Importantly, students are provided an opportunity to hear and learn

from each other's thinking. Moreover, because the students' thoughts are made visible to the teacher, he or she is then made aware of any gaps that need addressing when planning and directing the lessons (Whiteside, 2013).

Another example is think-puzzle-explore. It encourages students to identify specific aspects of a subject or topic (think), think about what puzzles them about it (puzzle), and then think about what to explore in more depth (Dajani, 2016; Ritchhart & Perkins, 2008; Wolberg & Goff, 2012). This framework focuses students' thoughts in order to generate deeper and more detailed understandings of a subjects and topics. As a result, students engage their cognitive skills and the mundane can be transformed into the fascinating.

When practicing thinking routines, students are acting out metacognition. Thinking routines transform theoretical, metacognitive constructs into realities, which has proven to be useful in developing cognitive capabilities that are transferable to contexts outside of school (Boix Mansilla, 2016; Lind, 2014).

However, while these routines encourage metacognitive thinking, they do not explicitly articulate the cognitive skills and capabilities students develop as a result of practicing them. Therefore, they do not provide clear ideals in relation to skill development nor explicitly relay their purpose to students.

2.4

Models of Engaged Learning and Teaching: Skill development made explicit.

The Models of Engaged Learning and Teaching (MELT) explicitly articulates the cognitive skills and affective states that students demonstrate and experience during learning (Willison, 2018; Willison & O'Regan, 2007). Educators in higher education have used the framework to guide course content, structure, and assessment over last 13 years (McGowan, 2018; Willison, 2018; Willison & O'Regan, 2007). In its most recent manifestation, MELT has six 'facets' which articulate various aspects of the affective and cognitive domains that students employ during inquiry learning (Willison, 2018) (see figure 1).

MELT facet verbs general	MELT questions general	Examples from others	Drivers and motivations
Embark and Clarify	What is our purpose?	Pose research question Define problem What is my aim?	Curious Empathetic Passionate
Find and Generate	What do we need?	Search strategy Data protocol What information do I need?	Determined Meticulous
Evaluate and Reflect	What do we trust?	Limitations and biases Contamination What are internal inconsistencies?	Discerning
Organise and Manage	How do we arrange?	Continuous line graph Non-continuous bar graph Writing structure Time and team management	Harmonising
Analyse and Synthesise	What does it mean?	Statistical trends Qualitative themes Making sense	Creative
Communicate and Apply	How do we relate?	Title Who is the audience? What next?	Constructive

Figure 1, MELT Facets, (Willison, 2019)

Both the cognitive and affective domains exist alongside each other, which reflects the fact that the two domains are connected (D'Mello & Graesser, 2012; Willison, 2018).

In addition, the MELT framework describes various levels of autonomy: 'Follow', 'Improvise', and 'Initiate' (Willison, 2019). This becomes particularly useful in the context of twenty first century skill development because autonomous learners will be more adaptable to contexts outside of the education system.

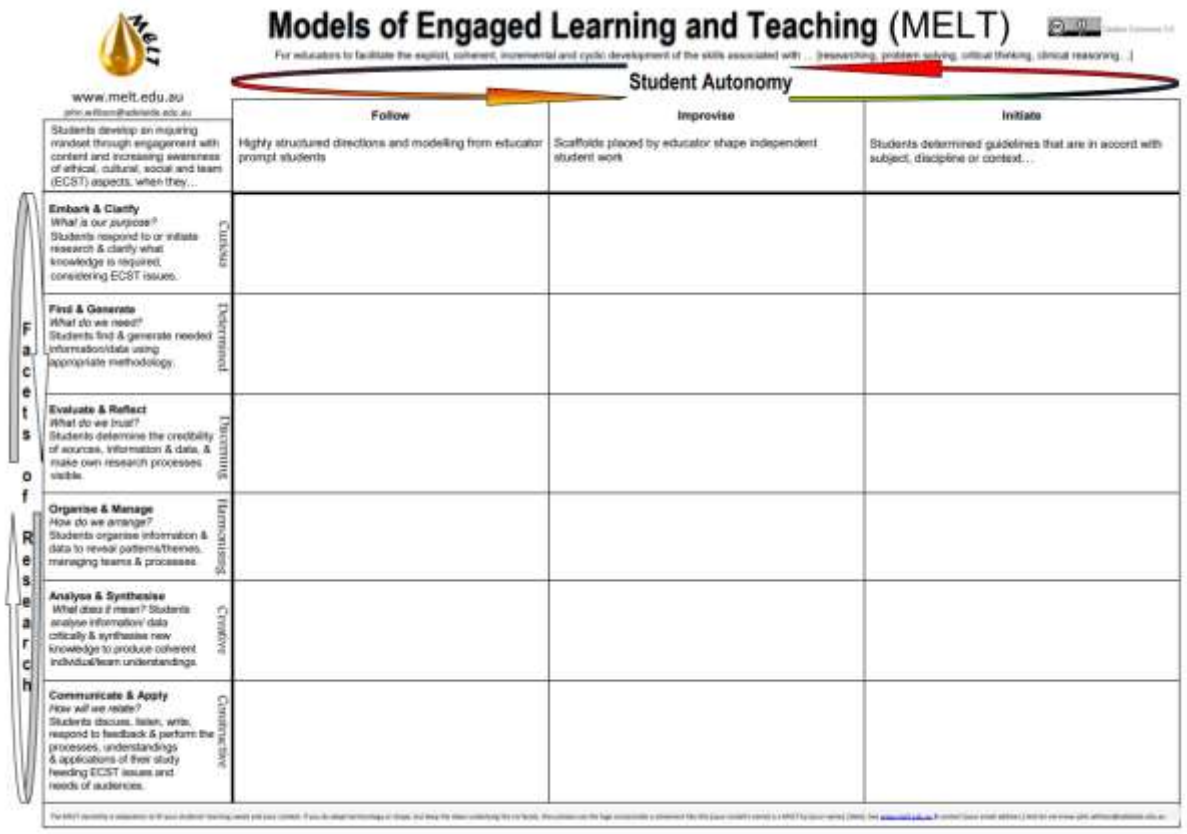


Figure 2 Willison, 2019

The framework was inspired by the Bloom's Taxonomy and 'the six standards of the Australian and New Zealand Institute of Information Literacy' (Willison, 2018; Willison & O'Regan, 2007). However, unlike these taxonomies, MELT does not organise

cognitive skills and affective states in a hierarchy. As a fluid framework, MELT can be easily adapted to a multitude of contexts, and its vernacular can be modified to suit the context in which it is to be employed (McGowan, 2018; Willison, 2018).

By adapting MELT to connect skill development with content knowledge, students are able to gather the information they needed to complete assessments, while exercising the necessary skills required by industry (McGowan, 2018; Moselen & Wang, 2014; Torres, 2018). Moreover, students become more independent in developing their skills outside of the course requirements (McGowan, 2018).

For example, MELT was successfully adapted to support undergraduates in improving their academic literacy (McGowan, 2018). Student's communication skills were explicitly taught without deviating from the course's content, which lead to improvements in student autonomy and skill development (McGowan, 2018).

Just as research and inquiry can appear 'unrelated to coursework' (Willison & O'Regan 2007, p. 398), secondary school subjects can often appear unrelated to industry. Explicitly focusing on the skills that students can transfer to higher education and industry has the potential to make subject content more relevant. For example, inquiry skills such as those articulated in MELT are 'central to professional life in the twenty-first century' (Bandaranaike, 2018; Lewis, 2002). Moreover, MELT has also been adapted into a 'Work Skill Development' framework, which illustrates its transferability to various industries (Bandaranaike, 2018; Willison, 2019). Therefore, MELT may support the explicit teaching of metacognition in order to help prepare students for successful employment in the 21st century.

Chapter 3: Methodology

This chapter explains the methodology employed to answer the research questions:

1. What is the nature and extent of student demonstrated engagement with and about the MELT framework?
2. When MELT is not used explicitly, what is the nature of student classroom interaction with relation to MELT facets and autonomy?

3.1 Context

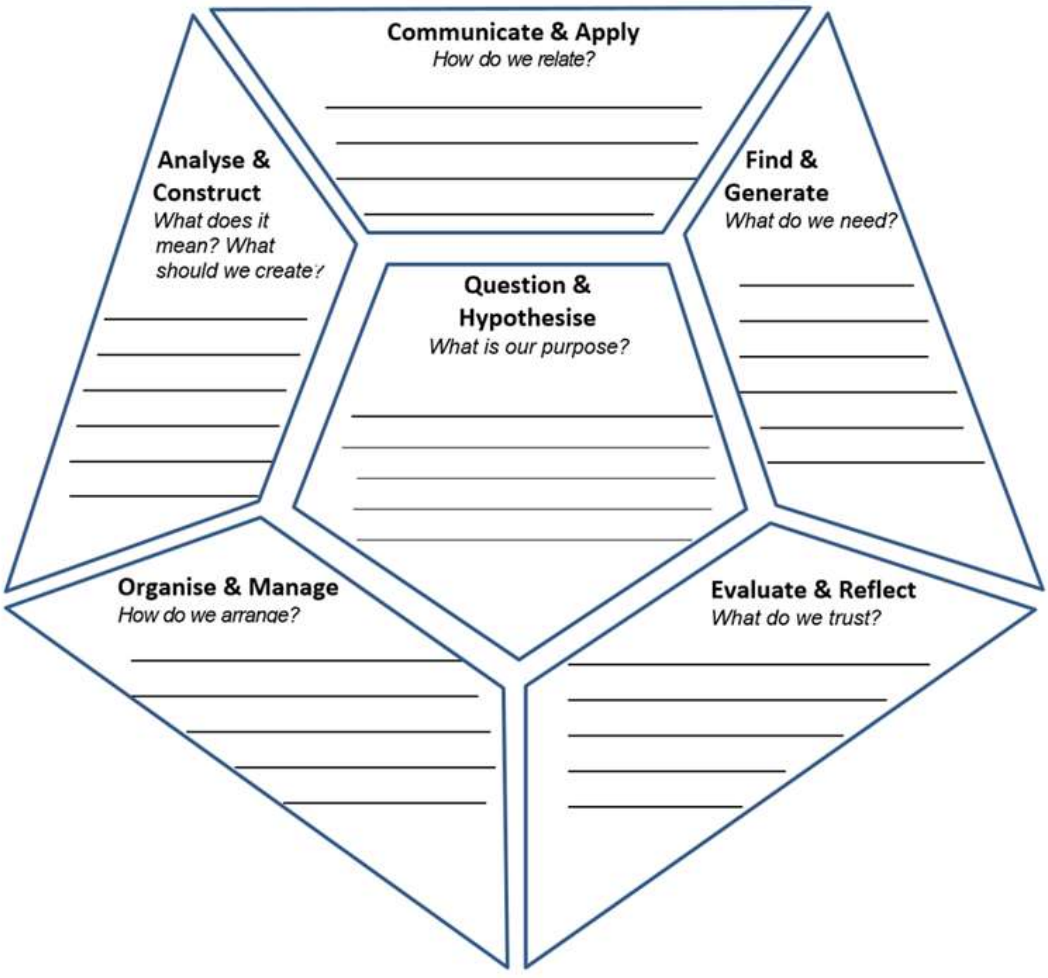
This study was undertaken at a Department for Education (DfE), secondary school in suburban Adelaide, South Australia. The school has over 100 teaching staff and over 1000 students (ACARA, 2018). The school's Index of Community Socio- Educational Advantage (ICSEA) was about average (ACARA, 2018). A year 11 chemistry class who were completing their SACE were the focus of this study.

The study was conceived when the school's deputy principal contacted John Willison from the University of Adelaide in 2018 in order to initiate the implementation of MELT. She had previously encountered the MELT framework while working for the Department for Education, and felt that it had the potential to support the school's students in becoming more aware of, and better able to articulate their cognitive capabilities – something she felt could improve student outcomes.

After consultations between John Willison and the school's staff, it was agreed that three classes would introduce the MELT framework in term 1 of 2019. Three teachers

volunteered to help make this possible. They all agreed to implement MELT into one of their classes. Three Master of Teaching students from the University of Adelaide volunteered to undertake the three studies. This study was one of them.

Joan, who taught a year 11 chemistry class, was aligned with one of the researchers for this study. John Willison, the researcher, and Joan met a few weeks before introducing MELT to the students. They reviewed the Research Skill Pentagon together, and discussed how it could be adapted to best suit the students.



Joan suggested making two changes to the pentagon. Analyse & Synthesise was modified to Analyse & Construct, and Embark & Clarify was modified to Question &

Hypothesise. Joan suggested this language would be easier for her students to interpret.

It was agreed that the researcher would observe seven chemistry lessons over the course of term 1. In the first lesson, John Willison introduced the students to MELT through an inquiry based, introductory lesson. Thereafter, the MELT framework and Research Skill Pentagon were not explicitly incorporated into their tasks. However, the researcher re-introduced the framework on three occasions. Except for the introductory lesson, and the three occasions when the researcher briefly reintroduced MELT, the teachers and students went about their lessons as per usual.

Throughout the seven Year 11 chemistry lessons, the researcher employed the participant as observer methodology in order to partake in and observe the students' interactions. This ethnographic study enabled the researcher to record the interactions of students while they undertook two assignments: a research essay and a practical test. The researcher focused on 5 students in particular, while observing and recording data about various other individuals, student groups and the class as a whole.

3.2 Ethics

The Human Research Ethics Committee provided ethics approval for the study before it commenced, and consent forms were provided to all students and parents or guardians. The students who were the focus of the study had returned completed consent forms. Both students and parents or guardians had the option to opt out at any time.

Pseudonyms were used for both the students and teachers in order to protect their identities.

Non-specific data from the My School website was provided in the methodology in order to protect the confidentiality of the school.

3.3 Applying thematic analysis

Thematic analysis is often used to analyse data in primary qualitative research, and was considered a useful tool in answering the research questions (Braun & Clarke, 2006; Fugard & Potts, 2015; Lin, 2018). Models and frameworks can help guide effective analysis (Daas & McBride, 2014). The researcher applied thematic analysis in order to uncover insights into student interactions with and about MELT. This process enabled the researcher to identify whether students act out the cognitive processes as they are described by the framework, as well as the students' level of autonomy. Furthermore, the researcher thematically analysed explicit student interactions with MELT in order to gauge students' current knowledge and awareness of their cognitive domains.

To clarify the study's validity, the research data was thematically analysed through a lens of previously observed phenomena that were already clearly defined in the literature outlined in the literature review. MELT provided the primary framework through which to analyse the data. In addition, literature on metacognition, flow and visible thinking routines informed the analysis. The literature supported interpretation of the data, and lead to the realisation of the 'underlying phenomena' (Fugard & Potts,

2015 p. 669; Braun & Clarke, 2006). Moreover, it provided a ‘structure and guidance for the activity of constructing arguments’ (Lin, 2018, p. 154).

3.4 Literature research methods

The researcher employed the University of Adelaide’s online library database to search for literature pertaining to MELT and metacognition. Search terms such as ‘metacognition’, ‘melt’, ‘visible thinking routines’, ‘flow’, and ‘research skill development’ were used in order to find literature.

Furthermore, the University of Adelaide’s MELT homepage was utilised.

3.5 Construct validity

MELT is a valid construct for interpreting student interactions. Its descriptions of 6 facets of student learning, and its claims about these human phenomena appear to be present in various educational contexts (McGowan, 2018; Torres, 2018; Willison, 2018; Willison & O’Regan, 2007). Furthermore, the heavy influence of constructs such as Bloom’s Taxonomy on MELT (Willison, 2018; Willison & O’Regan, 2007), signify that it has a solid foundation of clearly defined phenomena which have been observed and referenced in education for decades, and therefore it is clearly defined and sure of its ‘claims’ (Kane, 2012, p. 66; Chenail, Cooper, & Desir, 2019)

3.6 Qualitative versus quantitative

Various issues regarding qualitative and quantitative data were considered when deciding on how best to approach answering the research questions. Although quantitative data appears to hold a sense of certainty and fact, surveys and other quantitative data are questionable because they rely on participants' own ability to reflect on and articulate their behaviour and interactions (Berger & Karabenick, 2016). In the case of MELT, quantitatively gathering data would have been particularly difficult due to the limited exposure secondary students have in relation to the explicit articulation of the metacognitive domains. Students may not recognise the way in which their metacognitive processes work, and not understand MELT's terminology in the way that theorists do (Berger & Karabenick, 2016). Therefore, it would have been difficult to obtain reliable quantitative data. Furthermore, quantitative data analysis is not free of bias (Roger & Halas, 2012).

Participant observation

In light of this, it was decided to use an empirical approach to produce qualitative data. The most effective method for producing this data was deemed to be participant-observation because this naturalistic approach has been shown to produce rich and detailed data, which was essential to the analysis of the phenomena described by MELT (Guba & Lincoln, 1982; Laitinen, Kaunonen, & Astedt-Kurki, 2014). The participant observation methodology produced rich vignettes of student interactions in

the classroom. These enabled the descriptions of MELT to be ‘grounded in the data’ (Guba & Lincoln, 1987, p. 235). Furthermore, the participant observer methodology enabled the possibility for triangulation: the data and analysis included student perspectives, the researcher’s perspective, and theoretical perspectives.

3.8 Limiting bias

Before completing the observations, the researcher had only obtained a fundamental understanding of MELT, and a very limited understanding of the other literature outlined in this dissertation. Therefore, biases were less pronounced during the capture of data (Chenail, Cooper, & Desir, 2010). This was important because of the ephemeral nature of human phenomena, which, like knowledge, may not remain true or relevant forever (Guba & Lincoln, 1982; Siemens, 2005). As the researcher gained more knowledge he began to appreciate the data through fresh perspectives, raising ‘more questions’ (Guba & Lincoln, 1982, p. 237), which lead to further insights. For example, a better understanding of the metacognitive domains as provided by the literature provided insights into the causes of student disengagement.

The vignettes produced rich descriptions that may ensure that the data is transferable to future research based on differing suppositions (Guba & Lincoln, 1982). With shifts to what students should learn in the 21st century, the potential for reinterpretation may be useful (Kivunja, 2014; Lucas & Smith, 2018; Siemens, 2005).

Limitations of Participant Observation

However, the participant observer methodology had some limitations that needed to be considered before undertaking the research. An overt approach had the potential to interfere with the daily routine and regularity of the classroom, affecting data. However, it was not acceptable to perform covert observations due to the ethical issues this raises (Li, 2008). Although covert participant observation can lead to more insightful data, it may cause negative emotions to manifest in the researcher because it is deceptive (Li, 2008). However, a consideration of the covert approach was useful in highlighting the limitations of overt participant observation, such as reservations of participants in sharing information to an outside party (Li, 2008). In order to mitigate reservations of participants, and reduce disturbances to the natural environment, participant observation requires maximum involvement by the observer and participants (Li, 2008; Takyi, 2015). This ensures the researcher has a better understanding the context and has opportunities to build sufficient rapport with subjects (Li, 2008; Takyi, 2015). Therefore, during the observations, opportunities to interact with students and build rapport were considered paramount.

Chapter 4: Data

4.1 Context to the observations

Joan's class operated alongside another chemistry class. The two classrooms sat side-by-side, separated by a wall which had a partition left open in order for the teachers and students to move between the rooms if needed. Therefore, Dan, the other class's chemistry teacher, is mentioned in the data.

The two classes were independent, but, since they were both completing same subject, all students were given the same assessments, and were combined for the introduction and subsequent reintroductions to the Research Skill Pentagon. Furthermore, the two teachers, Joan and Dan, sometimes moved between classrooms to assist each other's students. As the researcher, I moved between the two classrooms and made observations indiscriminately of which teacher's class the student belonged. As a result, some of the students whom I focused on were in Dan's class, and some were in Joan's. However, it is not explicitly stated in the data which class students are in because this is not relevant to the study.

For our introductory lesson, John set up one of the classrooms so that both classes could combine for the entire lesson in one room, which was unusual. For the remaining lessons, the classes remained independent of one another, except for brief reintroductions to the RSP by the researcher, when the classes were briefly combined.

4.2 Lesson 1: Introduction to MELT

John, having mixed up his timetable, arrived a little early to the lesson. Fortunately, this gave him a chance to arrange the desks and chairs in order for two chemistry classes to combine for their introductory MELT lesson. Soon, the students began to filter into the room. Some stood just inside the entrance, waiting for instructions about where to sit in their newly-configured classroom, while others seated themselves at the tables. Once instructed, the whole class organised themselves in groups of three or four around each table. The students appeared intrigued by the presence of John and myself, watching us closely. One student asked me, ‘are you from the uni?’.

John and I took our positions at the front of the classroom, next to Joan. All students’ eyes were on John and I, silently and eagerly digesting the scenario. To begin the lesson, John and I introduced ourselves and the purpose of our visit. John then started up his PowerPoint presentation. To begin, he asked the students, ‘why does popcorn pop?’. The students remained silent. John enquired, ‘Has anyone cooked corn in the microwave?’. No students responded, to which John reacted with surprise. He asked for a show of hands and repeated his question, ‘Has anyone cooked corn in the microwave’? No one raised their hand. John appeared perplexed that none of the students had ever cooked corn in the microwave. He enthusiastically exclaimed, ‘*One hundred percent* of students have not cooked corn in the microwave?!’ The students smiled and laughed, feeding off John’s enthusiasm and his amazement at their lack of experience with corn and microwaves. He then asked for a show of hands, ‘who has cooked popcorn in the microwave?’ Everyone raised their hand.

John then introduced the first group task. In groups of two to four, students were asked to brainstorm possible sources for popping energy when popcorn is cooked, i.e., why does popcorn pop? They were instructed to categorise their answers under two headings: Chemical Change and Physical Change, which was modelled on John's PowerPoint slide (see figure 3). For motivation, John advised that the group with the most ideas would be selected to read out their responses.

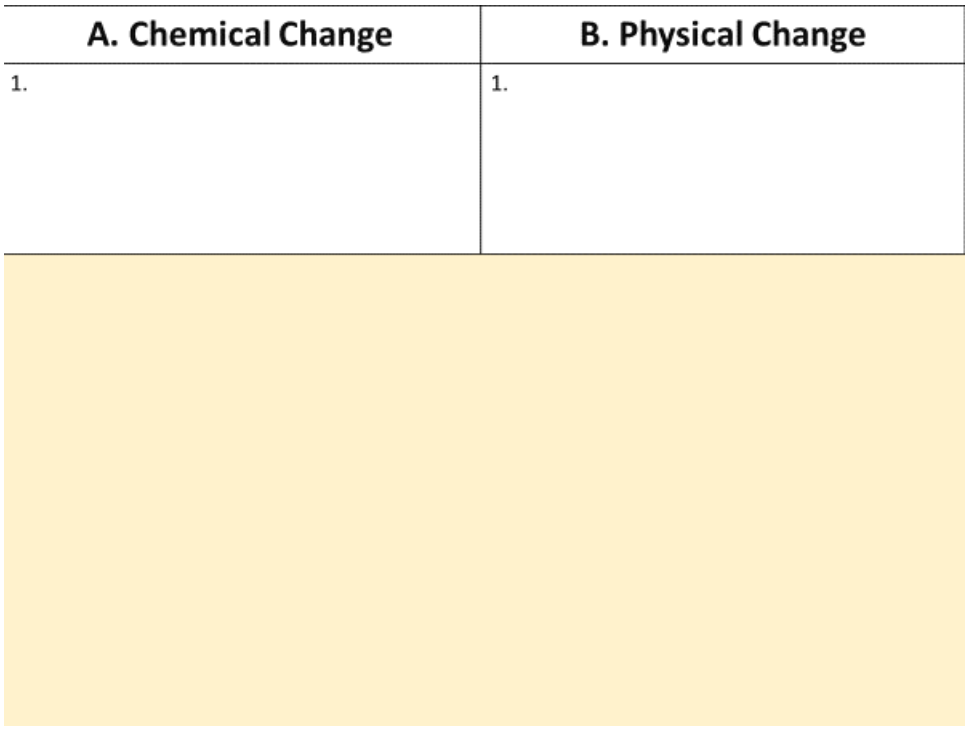


Figure 3 John's PowerPoint Slide

The students responded to their instructions with enthusiasm and went straight to work. In each group, students assigned an individual scribe. In one group, the scribe used his laptop computer to draw up a two-columned table in Microsoft Word with the required headings, 'Chemical Change' and 'Physical Change'. Everyone else used their exercise books. Some used a ruler and a pen or pencil to draw a table that reflected the example on John's PowerPoint presentation. One scribe wrote a more

simplified example: ‘Physical’ and ‘Chemical’ were transcribed onto a blank page in their exercise book. I noted the absence of borders or lines to delineate the headings.

There was a low murmur as students discussed their ideas in groups.

During this task, I approached a number of groups to see how they were going. Most groups had only one or two items for each heading. I could see a few groups had very few ideas, so I prompted them with a question: ‘what does popcorn look like before and after it pops?’. The students began to discuss my question, and generated more ideas.

John called the class’s attention back to the front and established which group had the most ideas. He then asked that group to read their ideas aloud. John recorded their responses on the PowerPoint slide. At this stage, most students appeared to be listening, with their attention focused on the students who called out answers or on the board where answers were being recorded. After the first group’s ideas were recorded, John asked for more ideas, which were offered periodically between moments of silence. The students required a little extra prompting from John in order to volunteer their ideas.

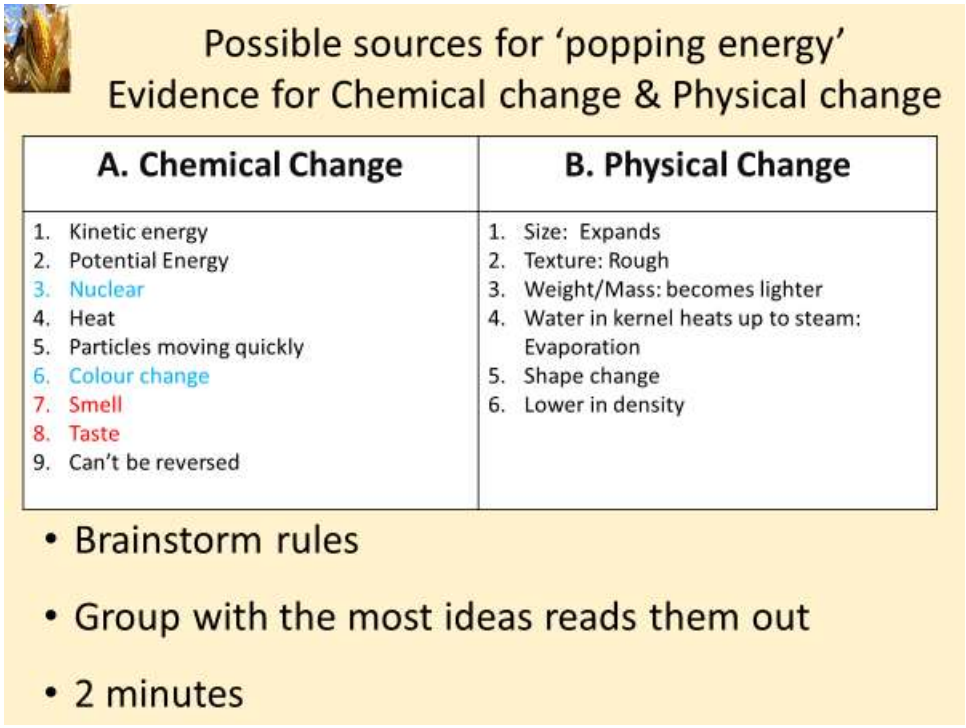


Figure 4 Students' Ideas

Once the students' ideas were recorded, John asked them to think about whether they would like to challenge any. Jimmy was the first student to volunteer to challenge an idea. 'Colour', he said, 'because 'it doesn't change'. He argued that the white of the popped popcorn pre-exists on the inside, and simply appears when it is popped. Jimmy then challenged 'smell' and 'taste' using the same argument. After that, another student challenged Jimmy's 'challenge' of taste, arguing that since there was a difference in the flavour of chicken before and after it is cooked, there must be a change in the flavour of popcorn. At this, the class became a noisy babble as small discussions broke out amongst groups, presumably communicating their opinions regarding the critiques.

John called the class's attention back to the front of the room and asked the students to tell him which skills they used to complete the previous task. Jimmy called out,

‘logic’, because ‘we have to think about an idea to see if it makes sense’. Another student offered, ‘experience’. John asked the class to volunteer ideas about what experiences they already had that might have informed them during the task. Someone called out ‘science’, another offered ‘different energies’. John asked, ‘any other knowledge we can draw on?’.

‘Cooking’, one of the students exclaimed.

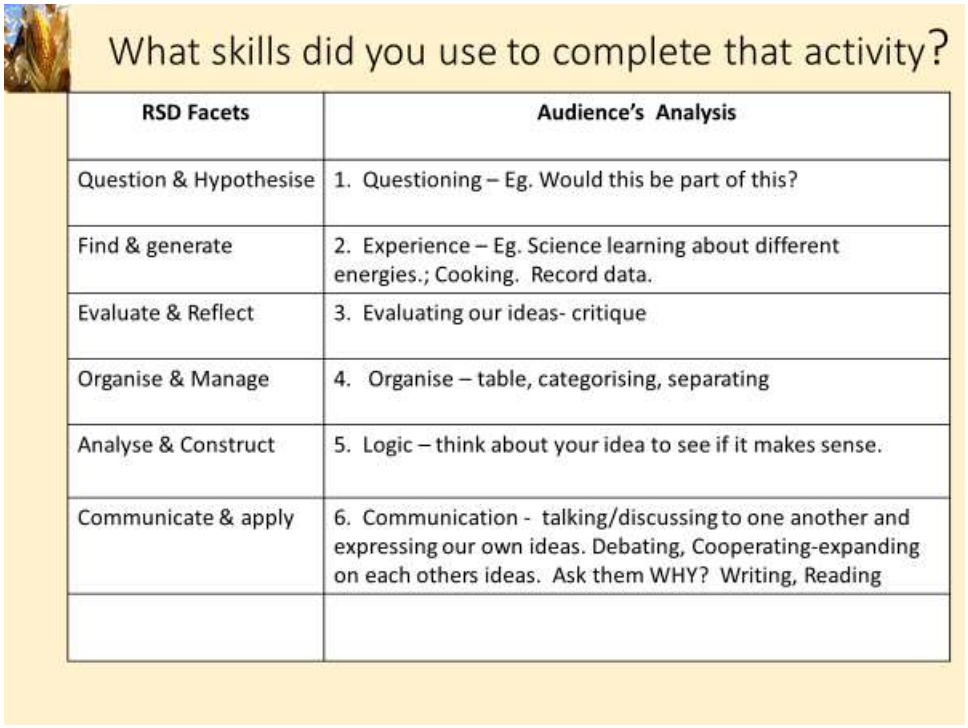
After some further prompting by John, one student volunteered ‘communication’. John asked for more ideas about communication: ‘Talking to one another, discussions’; ‘Expressing ideas’; ‘Debating’; ‘Cooperating’. John asked the class to expand on cooperating. One student responded, ‘if someone said a basic word, [such as] ‘form’, then someone else might explain how the form changes. Would *this* be part of this?’. John asked the students to offer another aspect of communication. The class remained silent for a few long moments. ‘What about what’s in front of you on your desks?’, said John.

‘Books’.

‘Yes, but what is it in relation to communication?’

‘Writing’, one of the students replied.

John then prompted the students further, in order to uncover the remaining skills they employed for their task. After a few periods of oscillations of silence and prompting by John, the students were able to identify the remaining skills; ‘evaluating your ideas: challenges the challenge’, ‘organising: recorded the data, catagorise, separating’.



What skills did you use to complete that activity?

RSD Facets	Audience's Analysis
Question & Hypothesise	1. Questioning – Eg. Would this be part of this?
Find & generate	2. Experience – Eg. Science learning about different energies.; Cooking. Record data.
Evaluate & Reflect	3. Evaluating our ideas- critique
Organise & Manage	4. Organise – table, categorising, separating
Analyse & Construct	5. Logic – think about your idea to see if it makes sense.
Communicate & apply	6. Communication - talking/discussing to one another and expressing our own ideas. Debating, Cooperating-expanding on each others ideas. Ask them WHY? Writing, Reading

Figure 5 Students' Responses

John moved on to explain the 'Research Skill Pentagon' (RSP), which took several minutes. Many of the students disengaged during this part of the presentation. Some took their phones out and engaged with these, while others stared blankly at their desks. Only a handful of students were focused on John or his presentation slide.

After describing the RSP, John asked the students to offer an alternative question for the facet, 'question and hypothesise'. Although none of the students immediately volunteered an answer, the call to action appeared to bring back the attention of the majority of those students who had disengaged: phones went back into pockets and all eyes were on John. The class remained silent for a few long moments. No one appeared able or willing to offer an alternative question.

John gave them one minute to create a question in their groups. The students began to discuss possible ‘question and hypothesis’ questions in a low murmur, while some began writing. After the minute was up, John asked if any of the groups would like to volunteer their question. The class remained silent. John selected one group and asked them what they had come up with. They were silent for a moment, reserved, until one student said, ‘ours aren’t very good’. John asked them to give their ‘not very good ones’ anyway. ‘What are you doing and how are you going to achieve it?’, they responded. John congratulated them on their excellent response and wrapped up his presentation.

Joan handed out an article about biofuels to each student, along with a list of points that students were supposed to address for their next summative task, a research essay. Each group was also given an A3 copy of the RSP. Joan explained to her students that they should read the article she handed out and summarise it. Upon receiving the handouts, a few of the students immediately began to read and highlight sections of the article. John explained to the students that they should analyse the information on the list of points they were given and write down which skills they might use during under each of the facets on their copy of the RSP.

One student pair began to discuss how the information from the list related to the pentagon. Another student completely disregarded the RSP, and continued reading and highlighting sentences from the article.

As I visited various groups, I discovered that a few appeared to be stuck. I asked one group if they understood what to do. ‘No’, they replied. I approached two other groups

who gave me the same response. Much of the talk I heard as I wandered through the room was off task. I began to help a few of the groups relate the points on their list to the RSP by asking questions such as ‘what are you going to analyse?’, ‘what are you going to communicate?’, ‘what skills will you use when researching this point?’. Most students responded with a blank look.

After a few short minutes it was time to pack up. John thanked the students for their participation and Joan wrapped up the lesson.

As they packed up, I asked one student about what he thought of the task he was given at the end. He said, ‘it doesn’t make sense’, ‘we went straight from other content to this topic’. I noticed he had not added any information to his pentagon, and had not shown any interest in reading the article.

These are some of the completed Research Skill Pentagons from their final task:

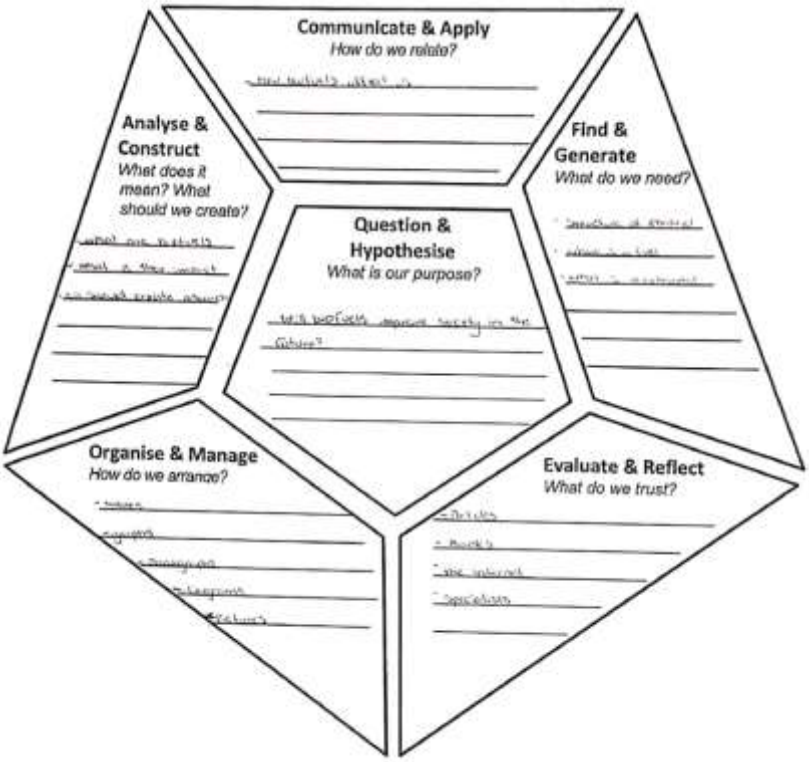


Figure 6

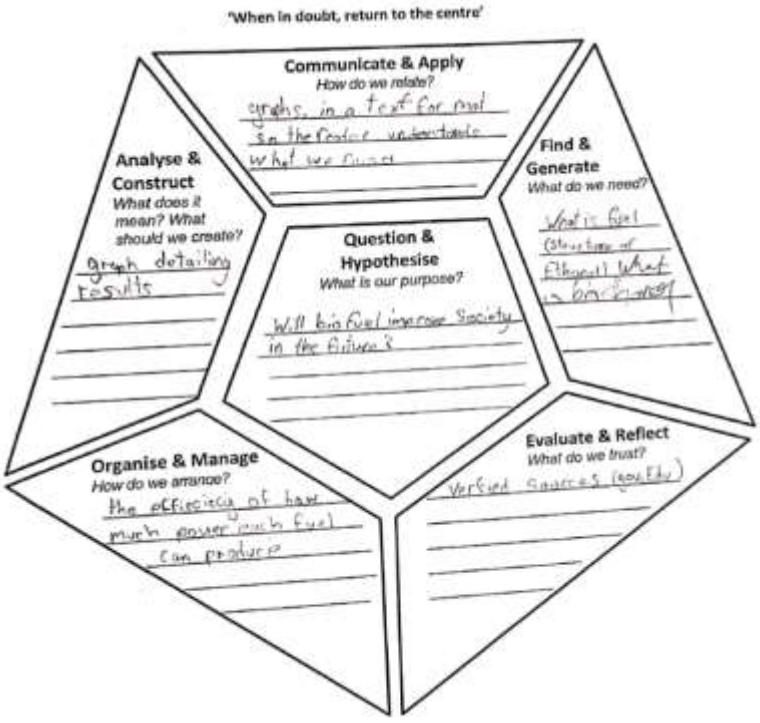


Figure 7

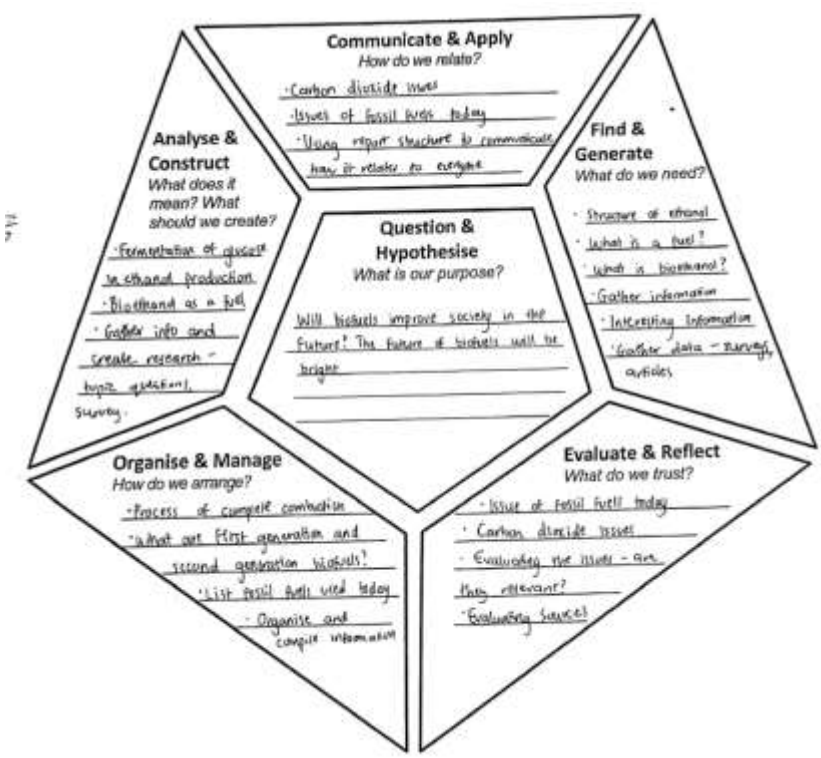


Figure 8

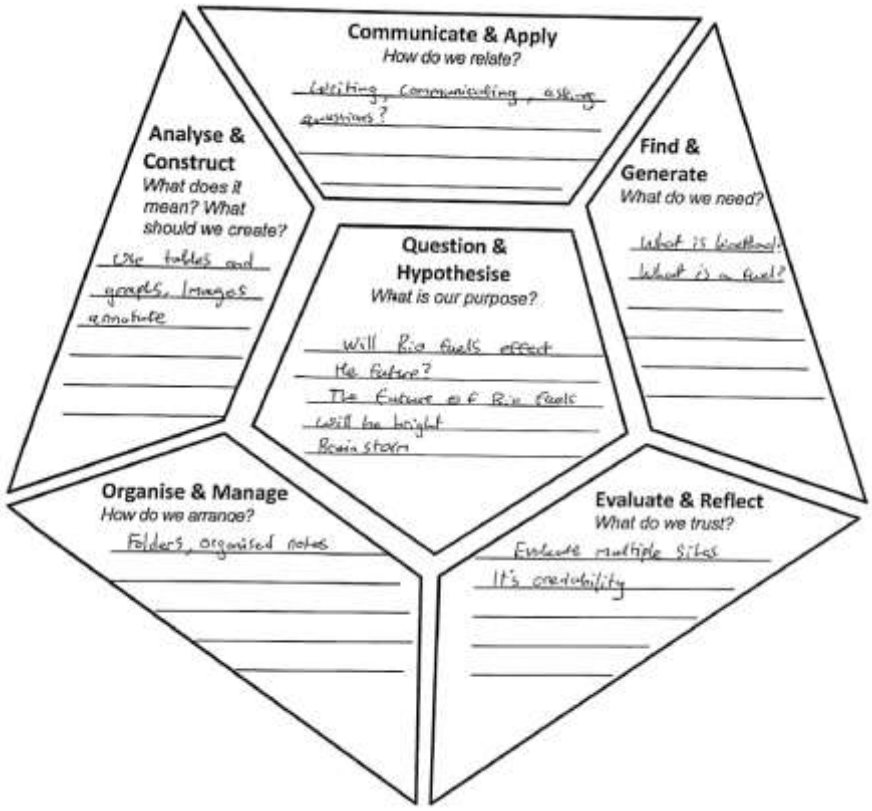


Figure 9

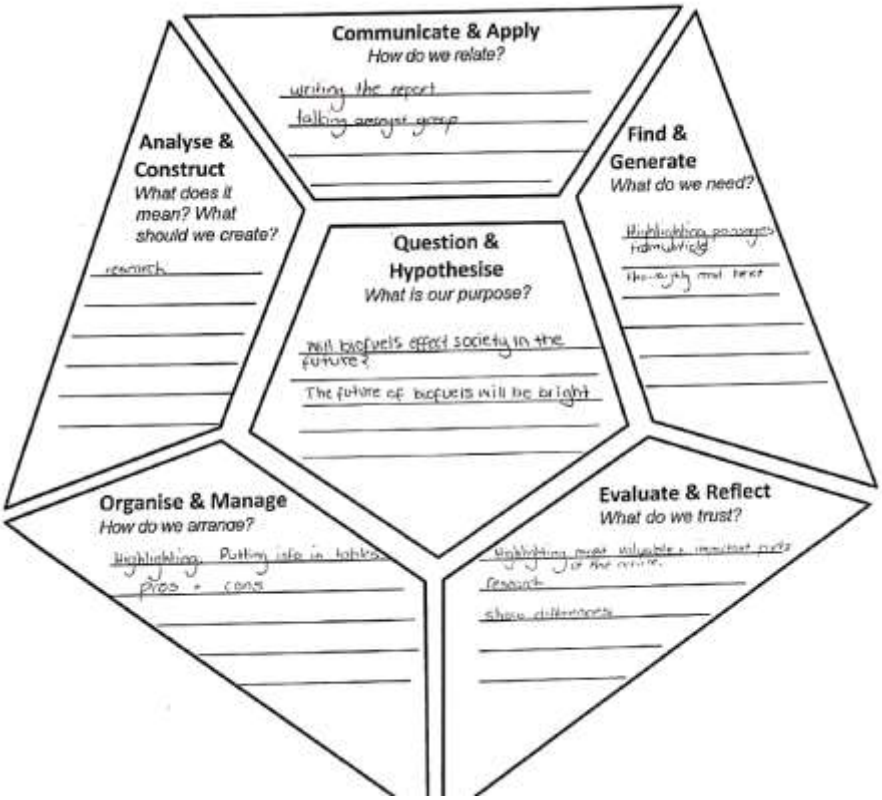


Figure 10

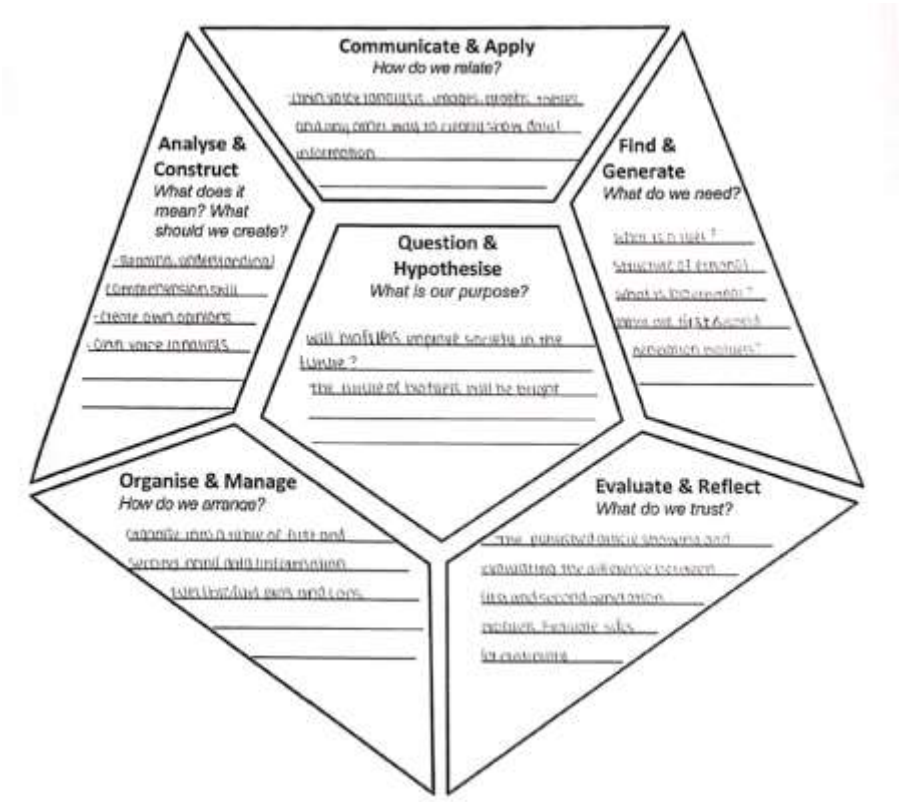


Figure 11

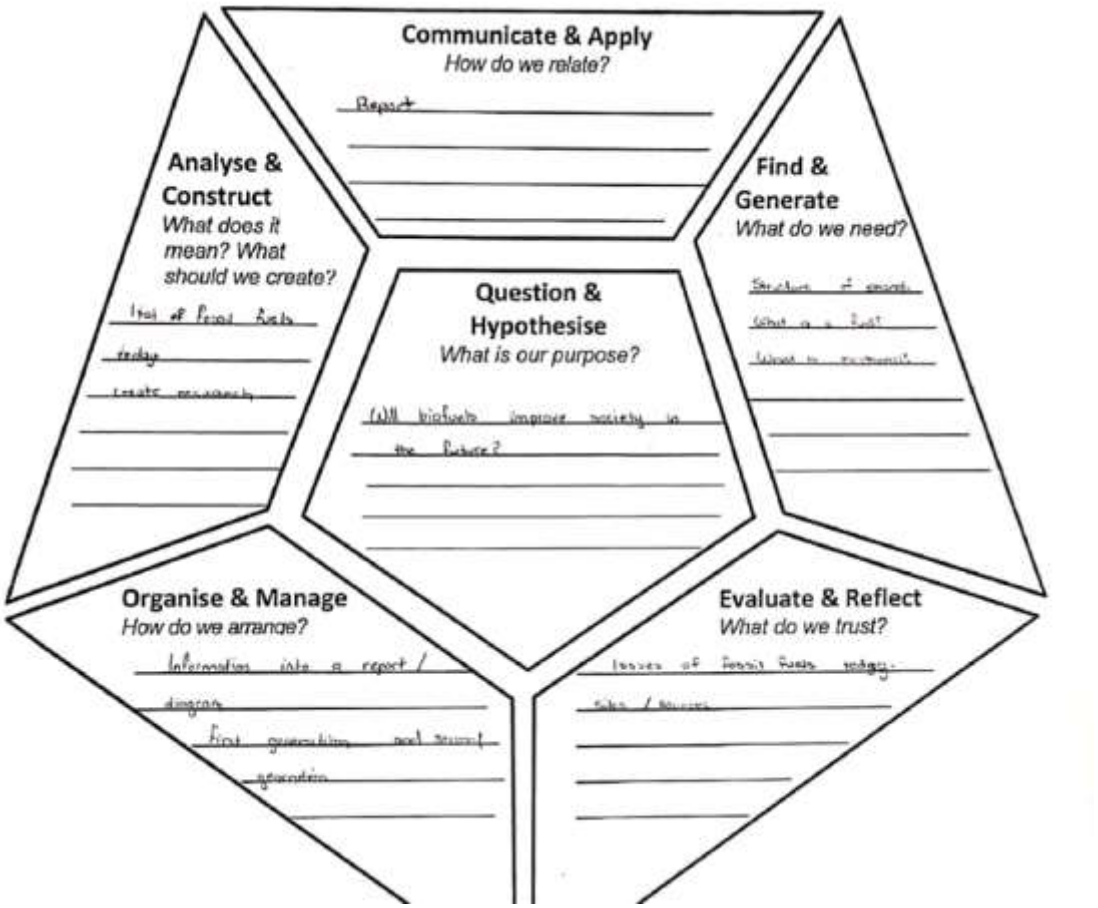

Communicate & Apply
How do we relate?
Report
Analyse & Construct
What does it mean? What should we create?
Find & Generate
What do we need?
Question & Hypothesise
What is our purpose?
Organise & Manage
How do we arrange?
Evaluate & Reflect
What do we trust?

Figure 12

4.3 Lesson 2: The Research Essay

As students entered the classroom they took up their usual seats and piled their textbooks and exercise books on their desks. The classrooms were back to normal, and the two classes were once again independent of each other.

I noticed two student pairs pull their A3, Research Skill Pentagons from between their pile of books and place them in front of them.

Joan instructed her students to read the article on biofuels that was handed out in the previous lesson, and to start thinking about how they would address the list of dot points in order to prepare for the research essay.

Early in the lesson, Jimmy brought his task sheet and Research Skill Pentagon to Joan. ‘Do I need to keep filling this in, or just read the article?’. Joan advised him to just read the article.

Most students were busy reading the article. Some had begun to highlight various sections. A few students had written headings in their exercise books and were copying information from the article underneath these. Others were discussing the article in pairs. Yet, there were a number of students who sat at their desks chatting, or staring into space as if waiting for further instructions.

I approached Amelia’s desk and asked her if she had read the article yet. She told me she had, so I asked her what she thought of it. She was unable to tell me much about it. ‘I tune out when reading’, she said. ‘I will probably have to read it again’.

As I approached Sarah’s desk, I noticed she and the student next to her had their maths methods textbooks open. They were making calculations in their exercise

books. I asked what they were doing. Sarah told me she studying for her maths methods test, which was due to take place in the following lesson.

As the lesson was wrapping up, I noticed two student pairs still had their Research Skill Pentagons on their desk, however, they were now piled under a heap of exercise and textbooks. I gestured to the RSP and asked them if it was helpful for this task. The students responded with a shake of their heads and a resounding ‘no’.

4.4 Lesson 3: The Research Essay

In the third lesson, students were expected to continue with their research task. They had been provided with a formative task sheet with two questions. One question asked them to summarise the article and the other asked them to make a comment on the credibility of the author. Most of the students were working on this task in pairs, although this was not prescribed. Many pairs had assigned one person to write, while the other searched for information from the article or the internet and read the relevant pieces of text aloud.

I asked Sarah about what she thought about the credibility of the author. She told me that she thought the author was fairly credible, but that he might be a little biased. I asked her why. She said the author came across as an environmentalist. I asked a few other students the same question. Most agreed that the author was credible, and they cited the many quotes and graphs from the article as evidence for this.

As I approached Amelia's desk I noticed she had started to work on summarising the article. 'I'm not sure if I've summarised it right', she said.

'Why don't you read it again to make sure?'

'No way am I reading it again. I'm struggling to focus'. Her head slumped to her desk. 'I'm feeling anxious because I'm falling behind in Research Project'. '*How* can you like English?' she asked me. She knew that I was a pre-service English teacher.

I noticed Jimmy approach Joan with a question, 'Is there a task sheet yet?' he said. 'Not yet, but it will be available soon', Joan replied.

I approached Sarah's desk as she was reading the article. I noted that she had highlighted each of the points on her task sheet in a different colour, and was highlighting various sections of the article with the colour that corresponded to each point.

Joan handed out the summative task sheet, along with the relevant SACE achievement standards. Some students began reading it right away, while others continued as they were, ignoring it.

I noticed that Taylor had drawn the symbol for hydrogen. Alongside this, she had written its formula. I asked her whether the symbol was necessary. 'You don't have to draw the symbol, but it helps me understand it because it is easier to visualise', she said. She pointed to the symbol, 'You can see *this* is connected to that'.

I returned to Sarah's desk. 'Which question will you answer first? I asked'

‘The second question, because the author is biased and a bit of an environmental type’.

‘So you want to ascertain his background before summarising his article?’

‘Yes’.

4.5 Lesson 4: The Research Essay

I noticed Jimmy had written ‘Persuasive Argument’ on the top of his page. I asked, ‘Oh, you’re making a persuasive argument?’.

‘Yeah, we have to. It says it on the assignment’.

‘Are you going to argue for or against biofuels?’

‘We should use biofuels so we have more time to crack cold fusion’.

‘Where are you going to get your information from?’

‘I’ve already got some’, he replied, as he pointed to his exercise book. ‘But I need to find more, especially graphs’.

I asked Nathan whether he thought the author was credible. He explained to me that he had discovered that the author was an ‘award winner’, which meant he was credible. He had written the author’s credentials as a list, below the question on the formative task sheet. I asked him how he was going to reference the information he found. He told me that he was going to use a ‘reference generator’ from the school’s intranet homepage. I asked him how he was going to search for information. ‘Just google’, he replied. He then explained that there was a database he could access through the school’s intranet but that he probably wouldn’t use it. Towards the end of

the lesson, he had begun going through the information he had written in his exercise book and was adding it to a Microsoft Word document.

In the final 10 minutes of the lesson, I presented the Research Skill Pentagon to briefly refresh the students on all six facets. Many of the students lost focus during my presentation, and began to chat amongst themselves. I had to keep asking for their attention. After my presentation I asked the class what kind of skills from the pentagon were they using while producing their research essay. The students were silent for a few long moments. I prompted them some more and offered a couple of examples. Finally, one student said ‘group work’. Then it was time to pack up.

4.6 Lesson 5: The Research Essay

I began the fifth lesson by reintroducing the MELT Pentagon. This time I had prepared a few slides about how the Research Skill Pentagon related to their research essay. As I went through each facet, I engaged the students by asking them how they had used the skills on the pentagon so far. Most the students remained engaged throughout the presentation as I asked the class questions. For example, as I was going through the Organise & Manage facet, I asked, ‘Has anyone finished their essay yet?’. Sarah was the only student to raise their hand. ‘Did you use any tools such as calendars to manage your time?’, I asked her.

‘No. I just had a date in my head of when I wanted to finish it.’.

‘Do you ever use a diary?’

‘No, I don’t need one’.

‘Do any of you use a diary?’, I asked the class.

About half of the students said ‘yes’, or nodded in agreement.
A student pair stated that ‘couldn’t live without one’.

After my presentation I asked for a show of hands to determine who had decided to argue for or against biofuels. The class was divided evenly. ‘Raise your hand if you think your opinion might change after you complete your research’, I said. About a third of the class raised their hands.

As I made my way around the classroom, Dan encouraged his students to share their research sources with one another. He told them it was important that if they found something useful that they share it with their peers.

I approached Sifa’s desk. She had a word document open with ‘Combustion’ written as the heading. The rest of the document was blank. I asked her how the task was going. ‘It’s confusing’, she said, ‘but Dan helped me out a bit’.

I returned a little later and found that she had made progress, with a neatly arranged graph in her word document that displayed the amount of energy required to produce various types of fuel.

Nathan spent the first part of this lesson playing chess with his neighbour. I asked them who was going to win. Nathan told me he hadn’t played before, and was just figuring it out as he was going along. I watched him try to move the horse across the virtual chessboard and fail. His neighbour told him that it moves in an ‘L-shape’. Nathan attempted to move the horse again, successfully.

I wandered over to Amelia's desk. 'How are you going to find the combustion demands for ethanol? I asked.

'I'll have to do some more research', she replied.

It was about midway through the lesson, and I could see she had spent most of her time playing 'MASH', a fortune telling game, to determine how her future would unfold.

I revisited Nathan, who had finished his game of chess and now had a word document open, full of text, images and graphs. I asked him if he had just copied the text or whether he had re-written it in his own words. He said 'already in my words, but I don't know if I will use it all yet'. He told me he was worried that he had too much information, as the word limit was 1000 words.

I asked Taylor how she was progressing. She told me the first question was the most difficult, which required her to find the energy required for the production and combustion of various fuels. 'She's found something useful', she said as she gestured to her friend. Taylor looked over her friend's shoulder to see what she had on her laptop and pointed to the text on the screen, 'that's the energy it takes in production, that's the energy it takes in combustion'. I asked Taylor where they had found the article they were reading. 'Jimmy sent us that link'. Jimmy was away sick, but had emailed them two articles he had found in his research. I asked Taylor if Jimmy's articles were helpful. 'The first link didn't work; the second link had some information but it didn't help with this question' she said. She pointed to the laptop screen again and told her friend, 'I think the table is all we can use from this one'. I remained at her table making notes while she and her friend searched for more information. 'What's

this one?', 'Have you found anything?', Taylor asked her friend as they searched for information. She studied one of the articles for a moment and exclaimed, 'By looking at the co2 emissions you can compare it, like maybe work out the percentage or something'.

Later, I approached Sifa, who was struggling to find information about the emissions produced during the production of various fuels. She told me she did not know how to calculate them herself. I asked Dan for clarification about the calculation of the emissions. He told me 'they haven't done that bit yet', referring to the formulas for calculating emissions, 'but they don't have to calculate it because can find the information about emissions online'.

I approached Sifa later in the lesson to see how she was going. She was using virtual sticky notes on her monitor to enter the due date for this assignment. I asked her what she thought of chemistry. She said, 'it's too hard', 'I am going to drop chem'. She had previously told me that in her previous school she did not do any research or essay writing. She simply prepared for and sat for exams.

Like Sifa, many of the students were stuck trying to find the data on co2 emissions. Nathan was one of these. He showed me his google search, which stated 'what energy is involved in getting petrol'. He had visited a couple of articles from the results list, but found they were too general in nature, and did not include the data that he needed. I encouraged him to modify his search terms to make them more specific. He then typed into the search bar, 'how much energy needed for production of petrol' (, ,). This impacted his results, significantly, and he was able to discover the data he needed.

4.7 Lesson 6: Preparation for the Practical Test

To begin the lesson, Joan handed out the task sheet for the students' formative task. The students were required to fill in a table with the various qualities of four substances, such as flame colour and melting point.

In Dan's classroom, he began the lesson by providing his students with a brief presentation about how to calculate the percentage of nitrogen from a chemical formula for fertiliser. When he was at the final stages of his calculation he asked for a volunteer to calculate the percentage of nitrogen based on the numbers he had presented. I noticed that Amelia was particularly engaged in his instruction, and she rushed to get her phone out to make the final calculation.

Sarah began the lesson with her text book open and her worksheet on her desk. She had begun searching for information in her books that would help her fill in the blank table. Suddenly she stopped searching and asked her friend, 'don't they have a diagram?'. She got up and went to the other classroom and returned a few moments later. 'It's blood red. I saw it on the poster', she said.
Having witnessed this, Joan reminded the rest of the students, 'there is a flame chart in the other classroom'.

Joan then asked the students, 'what do we need for something to be conductive?'.

The students remained silent. After a few moments Joan provided the answer. ‘I need you to start thinking about how you will find out if your ionic compounds are conductive or not, either as solids or liquid’, she instructed.

I approached Amelia to see how she was going with the table, but something else was on her mind. She told me about her English assignment, which she had submitted earlier in the week. She said she had written her entire English paper and then accidentally deleted it. So, she wrote it again. Afterwards, she re-read the task sheet and discovered that she had not completed her text as per the instructions. When she handed it to her teacher she told her that she would probably fail due to not understanding the instructions before writing. Amelia said that her English teacher agreed with her.

I noted that Taylor and Jimmy were communicating with each other about the task. They were working through their textbooks to find the information they needed to fill in their table. ‘Is that the same thing that is here?’, Taylor asked Jimmy. Jimmy read some of his answers from his text book, while Taylor transcribed them into hers. She used her calculator as if to practice the calculations and verify Jimmy’s answers.

Amelia looked over to Ted’s task sheet, which which had a completed table with all the information about the substances. She asked him, ‘how did you know that?, referring to the section about melting points (F=G).’
‘Easy when you look at the melting points’, he replied.

Amelia as she was completing her table by copying Ted's answers when Dan approached. 'How did you know that?', Dan asked her, pointing to her table.

'I copied from his', she replied.

'How did you know he is correct?'

'You just gotta hope'. Dan encouraged her to look for the other answers by herself, and advised her that she should be able to find the information in the textbook. Amelia opened her textbook and searched for the information. It took her some time, but eventually she found a graph which had the information she needed. 'I haven't been listening all year', Amelia confided after Dan had moved far enough away from her desk.

As I approached Sarah's desk she was discussing which tests she and her partner could rules out in completing the table of information about the substances. 'If we've got the flame colour, do you need to test this?', she said, as she pointed at the table.

Joan instructed the class, 'start thinking about what to test first'.

In went to the other classroom. Amelia was drawing a cartoon man on the whiteboard.

I approached Taylor and Jimmy again and asked, 'what are you going to test first?'

'Flame test first', Taylor replied.

Jimmy added, 'might be able to do a soluble test instead.'.

4.8 Lesson 7: The Practical Test

Today the students were tasked with a practical test. I began this lesson with another brief presentation on the six facets of the RSP and how they related to their task. As well as the presentation, I handed out a copy of the RSP to each student for them to fill in

First, presented on the facet Question and Hypothesise, and subsequently gave the students one minute to create a question or hypothesis for their practical test in pairs or small groups, and asked them to write their response on the RSP. As I wandered around the room, I found that many students were discussing other things, and many made no attempt at filling in their sheet with an answer. Half of the students had left their pens and pencils in the other classroom.

After one minute, I called the students' attention back to the front and asked for answers. Sarah quickly volunteered, 'To determine the chemical properties of specific substances', after which Jimmy called out, 'We are testing substances to practice what we will do when we become a chemist'.

I touched on the other facets more briefly with questions about how each facet related to their task. Various students provided a variety of responses which came without having to frequently prompt them or provide examples.

Their answers included:

Find and generate:

- ‘Burn it – flame colour’.
- ‘Dissolve it – tests electrical conductivity’.

Analyse & Construct: ‘What are you going to analyse today?’

- ‘Fire’
- ‘Colour of flame’
- ‘Electrical conductivity’
- ‘Results’

Communicate & Apply:

- ‘Verbal’
- ‘Written’
- ‘Facial expressions’
- ‘Classmates and teachers’
- ‘Diagrams’

Before I finished, I asked the students to fill in their Research Skill Pentagons after they finished their tests.

The class then divided into pairs and went about their tests. For their practical tests, students were to test the flame colour, conductivity, and solubility of four unlabelled, white substances and record their results in order to determine which substance was which. I focussed on two student groups throughout this process: Amelia and Ted, and Taylor and Jimmy.

4.8.1 Taylor and Jimmy:

As I approached Taylor and Jimmy they were discussing what they would test first. ‘Let’s do the flame test first’, said Taylor.

‘But we won’t be able to do soluble for this one’, Jimmy pointed out as he point to one of the substances on his task sheet.

I asked Taylor why she wanted to start with the flame test. ‘I want to do the flame test first because it looks good and I can see the flame’s colours’.

Jimmy replied, ‘but it’s more about the conductivity than the flame colour’. He had determined that he could reduce the amount of tests had to perform if they started with solubility tests. Amelia convinced Jimmy in end, and they started with the flame tests.

She opened one of the bottles containing white powder, and Jimmy took a small scoop and placed it into the flame of their Bunsen burner. The flame glowed bright red. I noted that behind the Bunsen burner, Taylor had set up her phone to record their experiment in video. I asked her what the video was for. She told me she was creating a time-lapse of their experiments.

Once they had finished their first flame test, Jimmy approached a desk where there was a bottle of hydrochloric acid and a jar full of test tubes. At this station students could clean their scoops so that they were not contaminated by the previous substance. I watched him as he stood still before the cleaning station for a few moments. ‘It says dangerous’, he said, finally. The bottle had a red warning label which said ‘dangerous’. I picked up the of the bottle, lifted its lid, which had a dropper attached, and replaced it. Afterwards, Jimmy picked it up, put a few drops of hydrochloric acid in a test tube, and began to clean his scoop.

Once back at his Bunsen burner, Jimmy began to burn the next substance. Dan was watching. ‘It should be going purple’, Dan said. The flame colour did not change. Jimmy took the substance from the flame and cleaned the scoop in acid for a second time. On this attempt, the substance glowed purple. I noted that Taylor had recorded their flame test results in a neatly drawn table, which mirrored the table on their task sheet.

After completing all flame tests, Taylor and Jimmy prepared for the soluble and conductivity tests.

4.8.2 Ted and Amelia

At Amelia and Ted’s workstation, Amelia opened a bottle with a white substance. Ted scooped a small amount and placed it into the flame. It burned bright red. Ted asked Amelia, ‘wanna take a photo?’.

‘Yeah’. Amelia retrieved her phone from her bag and took a photo.

While Ted burned substances, Amelia recorded the results on her task sheet. She did not draw a table like Taylor did, but instead spaced the results evenly so she could differentiate between the tests.

Once their flame tests were completed, Amelia began to compile the equipment needed for the conductivity tests. ‘Where does this go?’, she asked Ted, holding a red and black cables. She carefully studied the battery and fit the cables into the corresponding red and black sockets. Dan was standing by. ‘Test the battery first’, he said. Ted took the device from Amelia and squeezed the two metal prongs together. The light globe turned on. ‘What have we gotta do?’, asked Amelia.

‘We gotta put in these and then test them. I’ll get a peg’, Ted replied. Ted placed water into a test tube and dissolved a small scoop of one of the substances inside. He placed the metal prongs in the water and the light globe lit up. ‘Bubbling, turning yellow’ he said. Amelia recorded his observations on her task sheet.

‘Anything else? Is it getting hot?’ Amelia asked.

‘No’. Ted paused and watched the test tube closely. ‘Orange chunks’.

Once they finished the test, Amelia asked, ‘was it sodium chloride?’.

‘Yeah. Wait.’ Ted paused. ‘Sodium carbonate?’ Ted looked at the four bottles of white substances on his table.

‘Are you sure?’ Amelia asked.

‘No’.

‘Wanna do it again?’

‘Yeah. Did you write down what we saw?’.

'Yes'.

I gathered a few completed Research Skill Pentagons from the students at the end of the lesson. Here are two examples:

Sarah's RSP:

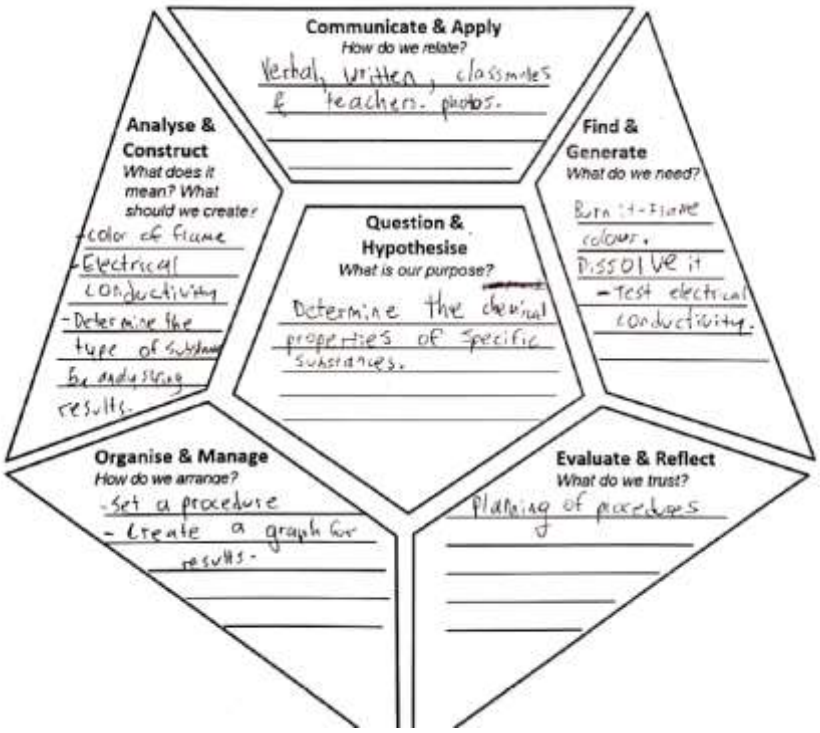


Figure 13

Jimmy's RSP:

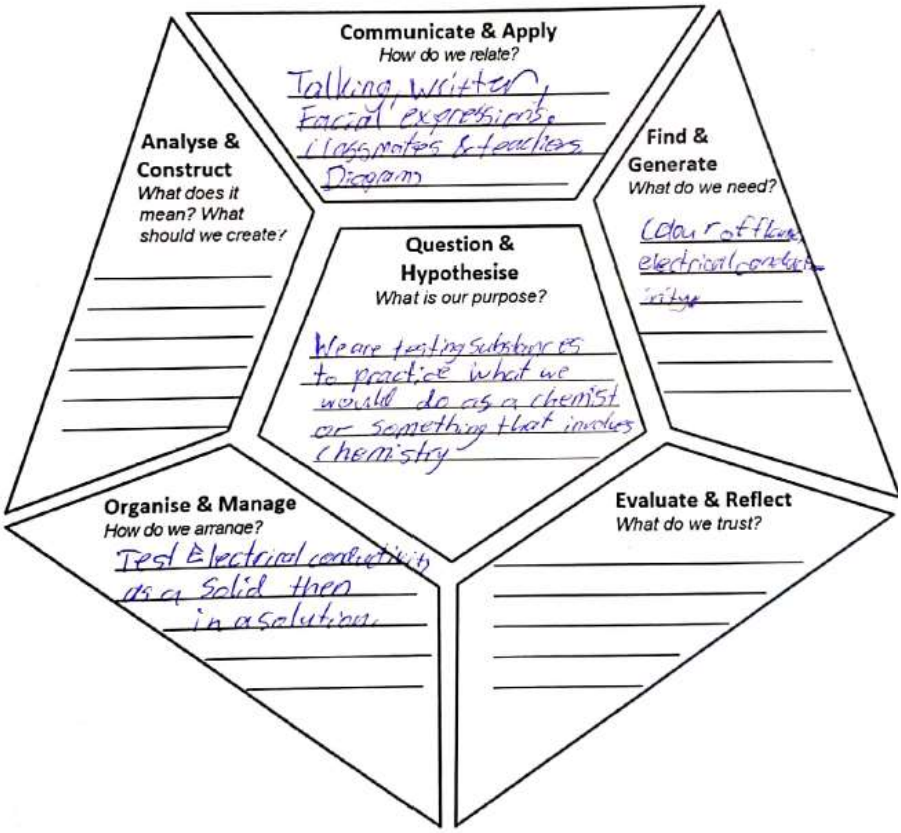
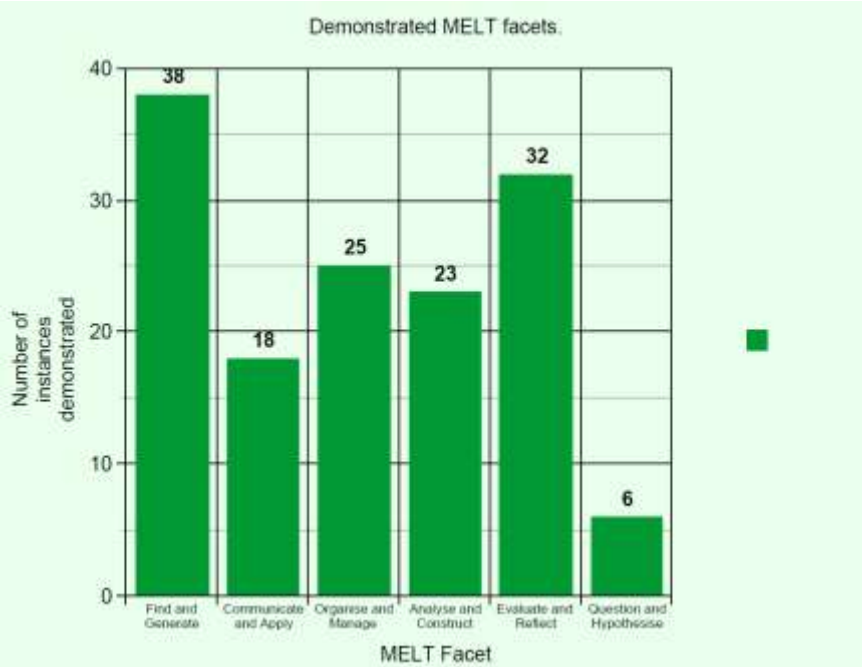


Figure 14

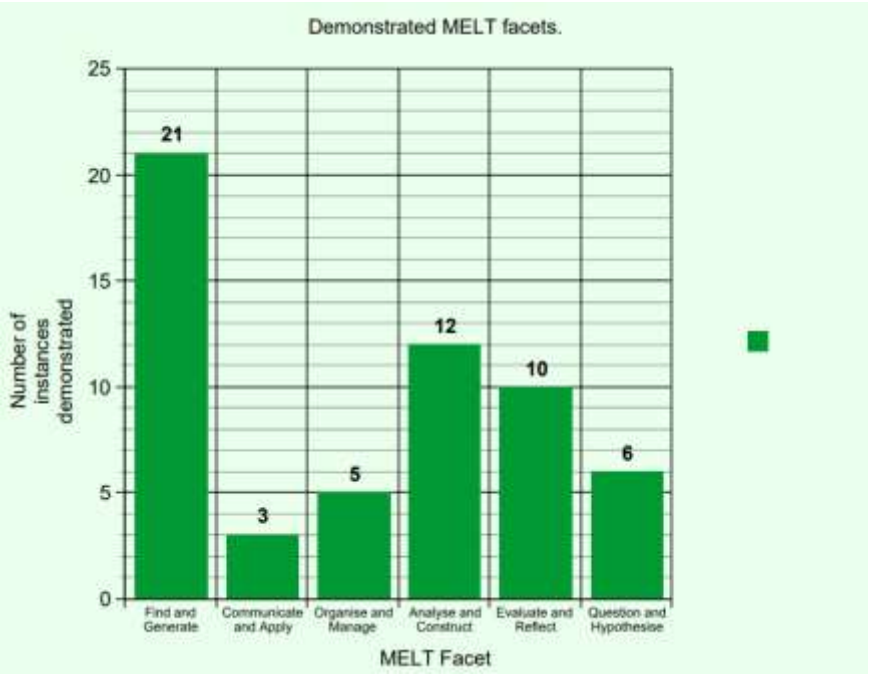
4.9 Graphs:

After analysing the vignettes for instances of demonstrated student interaction in relation to MELT I constructed two graphs. One represents lessons 1 to 5, while the other represents lessons 6 and 7.

Graph representing lessons 2-5:



Graph representing lessons 6-7:



Chapter 5: Analysis

5.0 Explanation of the structure of the analysis:

The chapter is broken up into two main sections. Section 1 is an analysis in relation to question 2, and the section 2 is an analysis in relation to question 1. Within these sections there are various segments, organised by student(s) and/or assignments and/or lesson(s). The structure is as follows:

1) **When MELT is not used explicitly, what is the nature of student classroom interaction with relation to MELT facets and autonomy?**
    a) Lesson 1: The Class in General.
    b) Lesson 2-6: The Class in General.
    c) Jimmy: Lesson 2-5 (Research Essay)
    d) Amelia: Lesson 2-6 (Research Essay and Theory for Practical Test)
    e) Amelia: Lesson 7 (Practical Test)
    f) Sarah: Lesson 2-5 (Research Essay)
    g) Taylor: Lesson 2-5 (Research Essay)
    h) Nathan: Lesson 2-5 (Research Essay)
    i) Sifa: Lesson 2-5 (Research Essay).
    j) Jimmy and Taylor: Lesson 7 (Practical Test)
2) **What is the nature and extent of student demonstrated engagement with and about the MELT framework?**
    a) Lesson 1: An Introduction to MELT.
    b) Lesson 2: MELT, Forgotten.

c) Lesson 4: First Explicit Reintroduction of MELT.
d) Lesson 5: Second Explicit Reintroduction of MELT.
e) Lesson 7: Final Explicit Reintroduction of MELT.

When MELT is not used explicitly, what is the nature of student classroom interaction with relation to MELT facets and autonomy?

5.1 Lesson 1: The Class in General.

The introductory MELT lesson was useful in uncovering students' demonstrated application of each of MELT's facets. John's opening activity where he asked the class about cooking popcorn enabled him to build rapport and illustrated the connection between positive emotion and student engagement. Feeding off John's enthusiasm, students demonstrated their enthusiasm for taking part in the generation of data, highlighting the importance of activating the affective domain to increase student engagement. John's enthusiasm produced a positive emotional response in the students, which lead to cognitive engagement, illustrating the connection between the cognitive and affective domains (D'Mello & Graesser, 2012; Willison, 2018).

In the second task, where students were asked to generate ideas about popping energy, the majority of students immediately demonstrated their ability to organise and manage data by employing John's example. This illustrated that 'directions and modelling' are often necessary to facilitate student engagement at the lower levels of autonomy (Willison, 2019). Yet, one student groups simplified John's example by shortening the headings and leaving out the lines. This demonstrated their ability to

evaluate and improvise, and highlighted that this group prioritised results over organisation and data management (Willison, 2019).

All groups displayed team management and communication skills when they assigned a scribe to record their ideas, which happened automatically and without conflict. The habitual nature of this process illustrated that these capabilities were already ingrained in the classroom culture.

Despite their communication, many groups struggled to find more than a handful of ideas, which may illustrate a lack of autonomy and that they need more guidance and structure in order to generate new information and ideas. However, students held knowledge but did not necessarily know how to access it. When I asked groups, ‘what does popcorn look like before and after it pops?’, the students re-engaged cognitively, and generated more ideas. They overcame the impasse which blocked their ability to think more deeply about the topic (D'Mello & Graesser, 2012; Ritchhart & Perkins, 2008; Wolberg & Goff, 2012). Questions may act as a portal into their cognitive domains, enabling students to access the knowledge they hold.

This sequence highlighted the potential for visible thinking routines to support students explore the idea of popping energy in more depth. Students often benefit from guidance in the form of questioning, which ‘is a recognised, sophisticated, complex teaching method, integral to student learning’ (Torres 2018, p. 18). In cases where visible thinking routines have been employed, they have encouraged students to explore topics and subjects more deeply, and therefore may have helped support student thinking in this case (Boix Mansilla, 2016; Grady, 2010; Kiener, Ahuna, &

Tinnesz, 2014; Lind, 2014; Ritchhart & Perkins, 2008; R. Ritchhart et al., 2011; Whiteside, 2013).

The students' long silences after John asked for contributions and answers illustrated a lack an interest in sharing their ideas. This reflects a common challenge when initiating new metacognitive frameworks that attempt to make thinking visible and engage students' in new cognitive pursuits (Bannister-Tyrrell & Clary, 2017; Dajani, 2016; Grady, 2010).

The task where students were asked to challenge fellow students' ideas was particularly enlightening. The idea of challenging other's ideas opened an opportunity for metacognition, a window through which the students could evaluate and reflect on each other's work. Jimmy's initial response, 'colour', demonstrated his ability to evaluate others' ideas. His elaboration of why popcorn challenged colour demonstrated his ability to reflect on and analyse his own response. These skills were also demonstrated by one of his peers, who critiqued Jimmy's challenge.

This sequence demonstrated the importance of questioning and guidance by the teacher in order to engage students' affective and cognitive domains, and, again, highlighted the connection between these domains (D'Mello & Graesser, 2012; Torres, 2018; Willison, 2018). The classes' cognitive engagement was evident when the whole group unconsciously broke out into small discussions, exercising their skills in evaluation, reflection, and communication. Meanwhile, positive aspects of the students' affective domains appeared as excitement and enthusiasm when the noise levels rose.

5.2 Lesson 2-6: The Class in General.

The students demonstrated a variety of skills as they went about completing their research essay. Highlighting the article about biofuels appeared to be a popular tool for organising data into two categories: useful and not useful. The students who wrote headings and began to collate information beneath these displayed organisational skills. All students operated well in pairs and small groups, and their discussions that were on task appeared to help the students find information and determine whether it was relevant for their task. Furthermore, their discussions demonstrated their communication skills, which appeared to help them engage with their cognitive domain by providing a platform for analysing and evaluating the information from the article. Communicating increased their efficiency. For example, pairs often assigned one person to write while the other found information to dictate.

Dan's encouragement for students to share their research articles was further evidence that the team management and communication skills were common elements in these classes' culture. Joan also demonstrated this aspect when she communicated that there was a flame chart in the other classroom during lesson 6, after Sarah had identified it. These examples bode well for the students moving into the workforce where these skills will be vital (Goldie, 2016; Kivunja, 2014; Siemens, 2005).

The analysis now proceeds on a student by student basis.

5.3 Jimmy: Lesson 2-5 (Research Essay).

Jimmy appeared better able to operate under clear instructions, and if he was confused, he was able to use his initiative to find the information he needed to continue. Initially, the RSP appeared to confuse him because it was not built into the assessment task - there were no instructions on his task sheet that related to the RSP. However, he sought clarification from Joan, demonstrating his ability to question and hypothesise in order overcome his impasse by employing his cognitive skills (D'Mello & Graesser, 2012; Rodríguez-Ardura & Meseguer-Artola, 2017; Willison & O'Regan, 2007). After obtaining the summative task sheet, and clarifying with Joan, Jimmy had the information he needed and was able to move confidently ahead with his research essay. This illustrates how imperative it is for teachers to set clear goals for students, especially when they are working at lower levels of student autonomy (Csikszentmihalyi, 1991; McGowan, 2018; Rodríguez-Ardura & Meseguer-Artola, 2017; Willison, 2019).

When I asked Jimmy about how he was going to approach his essay, he articulated his hypothesis, which included an argument in relation to cold fusion. This demonstrated that he was able to improvise, providing him a sense of control over his essay, which may have been critical to his engagement (Csikszentmihalyi, 1991; Rodríguez-Ardura & Meseguer-Artola, 2017). His insistence to me that he still needed to find more graphs, despite having already discovered some information relevant to his essay, demonstrated that he was already evaluating whether he had enough evidence to make a convincing argument. Furthermore, it appeared important to

Jimmy how he was going to display this evidence, which demonstrated that he was thinking about how to effectively communicate his arguments.

5.4 Amelia: Lesson 2-6 (Research Essay and Theory for Practical Test)

Amelia demonstrated her ability to think metacognitively and reflect on herself when she told me that she tuned out while reading. She was aware of her level of engagement, and knew that she could manage this by re-reading the text. However, this did not lead her to regulate her cognitive and affective domains in order to engage in the text. Her lack of confidence in her literacy became apparent later, which may help explain her disengagement (Csikszentmihalyi, 1991; Koehn, 2013).

In the third lesson, Amelia sought guidance from me in her pursuit to summarise the article, which demonstrated a lack of confidence in written work. Her comment, ‘How can you like English’ illustrated her disdain for reading and writing.

The story she recounted to me about her English assignment was further evidence of her lack of confidence in her literacy skills, and may help explain her disengagement in the research essay (Csikszentmihalyi, 1991; D'Mello & Graesser, 2012; Koehn, 2013). It seemed she had continually hit obstacles and failures throughout her attempts at academic writing. Therefore, she may have reached a level of disengagement described by D’Mello & Graesser, that could be described as boredom (2012). Therefore, tasks that focused on reading, writing, and analysis may have appeared especially difficult to undertake.

Furthermore, the presence of anxiety, due to her fears of falling behind in research project, highlights how difficult it would have been for her to effectively re-engage in literacy-focused tasks (Koehn, 2013). While this signifies the importance of time management and organisation skills in secondary education, it further illustrates the impact of anxiety on a students' ability to cognitively engage (D'Mello & Graesser, 2012; Koehn, 2013). Her expectations of low academic success and previous disappointments that resulted from reading and writing related assignments appeared to make the research essay appear void of any opportunity to feel the sense of competence that is imperative to engagement (Harmat et al., 2016; Maslow, 1943; Moseley et al., 2005; Rodríguez-Ardura & Meseguer-Artola, 2017).

Nevertheless, Amelia's identification of her anxiety and inability to focus demonstrated metacognition: she expressed explicit knowledge of an aspect of her affective domain. However, this did not lead to the regulation of her affective domain, and was instead used as an excuse for disengagement. This highlighted the gap between knowledge of and regulation of the metacognitive domains, and strengthens the argument that the explicit teaching of metacognition may be necessary in order to improve regulation (Bannister-Tyrrell & Clary, 2017; Flavell, 1979).

5.5 Amelia: Lesson 7 (Practical Test)

The juxtaposition between Amelia's level of engagement during the research essay and the practical tests demonstrates the significance of the affective domain in students' ability to cognitively engage (D'Mello & Graesser, 2012; Koehn, 2013). Amelia demonstrated confidence in her cognitive abilities during the practical test: She

took responsibility and set up the equipment, managed the data, generated data, questioned Ted to ensure they had valid results, and she analysed and constructed new meanings using her phone. This demonstrated that she engaged five of the six facets of MELT. Amelia's enthusiasm for making the calculation of the percentage of nitrogen after Dan's presentation reflected a sense of confidence yet again, highlighting the link between confidence and cognitive engagement (Koehn, 2013). Therefore, she had the capabilities required for both tasks, but was not able to engage these easily during the research essay. This may be a result of a persistent feedback that she was not competent at literacy-based tasks, leading to boredom and depleting confidence (Csikszentmihalyi, 1991; D'Mello & Graesser, 2012; Koehn, 2013). I would argue that a more skills-based focus during her education may have helped her realise a sense of competence in her literacy.

5.6 Sarah: **Lesson 2-5 (Research Essay)**

When Sarah studied for her maths methods test, instead of completing the task prescribed by Joan, she demonstrated a multitude of facets from the Research Skill Pentagon. As she went through her textbook, she demonstrated her ability to find information in order to analyse it and construct solutions. By prioritising her maths test over her Chemistry task, she demonstrated her evaluative skills. In her evaluation she had to consider time management. She determined that she should prioritise her test over her current task because she was not yet given a due date for her chemistry assignment. However, this highlights that students often prioritise results over skill development and reflects findings that teachers are often results-driven (McGowan,

2018; Torres, 2018). Furthermore, this illustrates the motivational power of summative assessment (Hickey, Kruger, Fredrick, Schafer, & Kindfield, 2002; Trotter, 2006).

When Sarah finally began her research in the following lesson, she appeared to have identified an inherent bias in the article about biofuels. This demonstrated her ability to evaluate data before accepting it. However, her analysis hints that her own biases affected her interpretation of the article and that she may benefit by developing skills in reflection in order to apply her critical thinking to her own analysis, too.

The fact that most of her fellow students accepted the author's work without identifying any bias shows that their analysis was perhaps a shallower than Sarah's, and that they may benefit from the explicit development of critical thinking and analysing. However, the fact that most students cited the author's use of quotes and graphs as evidence for the author's credibility demonstrated their ability to analyse texts.

Finally, by colour-matching sections of the article with the dot points from her list, Sarah displayed an ability to organise and manage data. She was the first student to finish her essay, which highlights that data management and organisation skills can lead to increased efficiency.

5.7 Taylor: **Lesson 2-5 (Research Essay)**

Taylor recorded hydrogen in the form of a formula and in the form of a symbol, which demonstrated her communication and application skills. Furthermore, she used this to attain clarity over the meaning of hydrogen. Her reflections related how the symbol helped her 'visualise' hydrogen, while her analysis described how the symbol makes the concept of the atom clearer.

In the sequence where Taylor was finding information with a partner, she demonstrated all six facets. When communicating with her partner and Jimmy via email, she was able to find useful information. This highlighted the significance of developing the cognitive skills required for managing information networks (AlDahdouh, 2017; Goldie, 2016; Siemens, 2005). Taylor was able to keep an information flow open with Jimmy, which made her own research more efficient, demonstrating how social and communicative skills can lead to greater efficiency and benefit learning (AlDahdouh, 2017). She used the internet, too, to connect to other information networks, which increased her opportunities to find useful data ((AlDahdouh, 2017; Goldie, 2016)).

Upon finding relevant articles, she evaluated them by questioning their content aloud with her friend. Furthermore, she analysed their results to determine how she might best communicate them. Consequently, Taylor demonstrated how students employ various skills in a non-hierarchical fashion, highlighting that the fluid nature of MELT reflects the realities of student interactions in the classroom (Willison, 2018, 2019; Willison & O'Regan, 2007).

5.8 Nathan: Lesson 2-5 (Research Essay)

Nathan demonstrated that students often choose to do what is expedient rather than that which exercises skill development. Despite knowing that he had access to an academic knowledge database through the school's intranet, Nathan evaluated that Google would be able to provide him with enough information for his essay. It

appeared that Nathan did not feel the need to challenge himself to find more credible sources because it was easier to 'just Google' it. This illustrated that it is not expected that secondary students demonstrate their ability to evaluate and reflect on the legitimacy of sources for research, which may highlight the need for the explicit development of such skills (McGowan, 2018; Willison, 2018; Willison & O'Regan, 2007). This does, however, demonstrate Nathan's time management skills, as it he employed an efficient method to find the information he required, despite the detriment to his research skill development.

Although Nathan's game of chess was off-task, the sequence clearly demonstrated the affective and cognitive processes described by flow and MELT. His unsuccessful attempt to move the horse lead to an impasse (D'Mello & Graesser, 2012). However, his move demonstrated his ability to find and generate data (Willison, 2019). Nathan's impasse was recognised by his friend, who offered further information in order to help Nathan overcome it: 'L-Shape'. Nathan took this information, analysed how it might apply to the game, and was ultimately rewarded with a successful move of the horse. By exercising his cognitive skills, Nathan was able to return to a state of flow and achieve a sense of competence.

Having returned to his research essay, Nathan employed various facets of MELT, yet highlighted where his skills needed improvement. He demonstrated his ability to find information, analyse it and re-construct it into his own words. Furthermore, he evaluated and reflected on his data and determined that he may have had too much. However, he appeared anxious about how to condense it. He was having trouble managing his data, which illustrated that organisation, management, evaluation and

reflection are significant aspects of research and writing. His anxiety about having too much information highlighted that he may need support to develop these skills further, which suggests the need for explicit skill development (McGowan, 2018; Willison, 2018; Willison & O'Regan, 2007). Joan reported to me a few weeks later that about half of the class had submitted their final essays over the word limit, which supports this assertion.

When Nathan was having difficulty finding useful, google search results, he demonstrated that students often need to evaluate and reflect on their own practices in order to improve. However, cognitive engagement such as this does not naturally result from encountering an impasse. When I prompted Nathan to reconsider the terms he used in his Google search, Nathan was able to demonstrate these skills, highlighting the value of the teacher's awareness of student obstacles (D'Mello & Graesser, 2012; Whiteside, 2013). By reflecting and evaluating, he was able to improve his search terms and garner better results; by deliberately employing his cognitive capabilities, he uncovered more useful articles. This sequence demonstrated that when finding and generating data, students can benefit from the deliberate use of evaluation and reflection, illustrating the non-hierarchical nature of research skill development, and highlighting the need for more explicit skill development (McGowan, 2018; Willison, 2018; Willison & O'Regan, 2007).

5.9 Sifa: Lesson 2-5 (Research Essay)

Sifa demonstrated her ability to question and clarify as a way of overcoming confusion. When Sifa reached an obstacle in progressing through her research, she sought

clarification from Dan in order to move past it. However, Sifa's reliance on her teacher for clarification shows that she may have needed clearer goals and more structure. For this particular task, she was operating at a relatively low level of student autonomy, which reflected her limited experience in writing research essays in chemistry.

Juxtaposing her experience with Jimmy's shows how students may be on various places on the spectrum of autonomy, and that teachers should endeavour to uncover where their students sit on this spectrum in order to prioritise support or provide more challenges.

5.91 Jimmy and Taylor: Lesson 7 (Practical Test)

Jimmy clearly valued succeeding as per the task sheet as efficiently as possible. He was results driven, aiming at the extrinsic goal, while Taylor was motivated by the intrinsic quality of the tests: the spectacle and discovery. The sequence illustrated that Jimmy was cognitively engaged in the task sheet by employing his analytical skills, while Amelia was motivated by potential, spectacular results, through which she could take control and exercise her creative skills. Jimmy engaged his analytical skills when he thought about what the tests could mean for determining which substance was which. On the other hand, Taylor's engagement was characterised by her creativity as she used her phone to construct new meaning from the experiments, an improvisation not required by the task sheet. By employing her phone as a way to record the experiments she was also constructing another way of communicating the results and grasped a sense of control, which may have been necessary for engagement (Rodríguez-Ardura & Meseguer-Artola, 2017).

Their early disagreement about what to test first lead to an impasse, but Jimmy eventually conceded in order for their experiments to go ahead. This illustrated their ability to communicate in order to manage their team and organise their tests, something which reflected earlier observations about the team management and communication skills being part of the classroom culture.

When Jimmy stood still at the cleaning station he demonstrated how challenges can be overcome through cognitive engagement. He knew that he needed to clean his scoop, but evaluated that the warning meant he should not touch the bottle. His frozen stature indicated that he had reached an impasse. He needed more information in order to analyse it and move ahead. The information he needed came from myself when I touched the bottle. Jimmy analysed that this meant the bottle must be safe to touch, illustrating a link between find and generate and analyse and construct, and highlighting that various skills need to developed in conjunction with one another.

Jimmy demonstrated his ability to analyse the results of his test. Based on Dan's advice that the substance 'should be going purple', he analysed that his scoop may be contaminated, therefore, he cleaned the scoop, which lead to a successful flame test.

The previous two sequences highlight the significance of teacher-student interactions in the classroom in order to overcome obstacles and enable students to exercise their cognitive skills and re-engage in tasks. Moreover, these show that secondary students may often sit on lower levels of autonomy, and may not improvise or initiate without guidance.

The following proceeds with an analysis of the vignettes in relation to the first question: What is the nature and extent of student demonstrated engagement with and about the MELT framework?

5.92 Lesson 1: An Introduction to MELT

Students had their first opportunity to explicitly engage with MELT when John asked the students to reflect on the cognitive skills they employed in order to complete the popping energy task. Jimmy demonstrated his ability to reflect on and analyse his own thoughts when he asserted that he used 'logic', 'because in order to make sense of something you need to think about it'. Furthermore, in reflecting on *why* logic is important, he displayed the ability to think metacognitively (Bannister-Tyrrell & Clary, 2017; Flavell, 1979). His response was juxtaposed against the other students' responses, which arose as single word answers: Unlike Jimmy's analysis, once a simple answer was generated there was no apparent consideration of what the response might mean. This demonstrated that students were more focused on results than processes, and that metacognition and cognitive skill development may need more explicit development (McGowan, 2018; Trotter, 2006). Furthermore, this highlighted the need to explicitly teach evaluation, analysis and construction in order for students to deliberately engage these facets (Bannister-Tyrrell & Clary, 2017; McGowan, 2018; Oliver & Venville, 2017; Torres, 2018; Willison, 2018; Willison & O'Regan, 2007).

During John's explanation of the Research Skill pentagon, students demonstrated their lack of cognitive engagement. The student's disengagement can be explained through the concept of flow, for it was missing the elements that lead to cognitive engagement (Csikszentmihalyi, 1991; D'Mello & Graesser, 2012; Rodríguez-Ardura & Meseguer-Artola, 2017). They were not prescribed a task or asked any questions during the presentation, and therefore they could easily allow their cognitive abilities to lay dormant. There did not appear to be any external motivators such as summative assessment to motivate the students, and no opportunities to engage higher order thinking. Furthermore, no clear goals were set during this sequence, and there was no scope for students to test their competence during the presentation. Despite this, some students remained engaged, which I suspect may be a result of the operations of the affective domain, although the underlying motivations and emotions of students remained unclear.

Finally, when the students were tasked with relating their research points to the Research Skill Pentagon, the students were asked to think metacognitively. They were required to exercise cognitive skills such as evaluation, reflection, analysis and construction. Some of the groups' confusion over this task illustrated that they were at the 'follow' stage of student autonomy and required further support (Willison, 2019). Highlighting this was the fact that only one of the seven groups who completed the RSP came close to identifying the skills they might use for analysis and construction: 'Create own opinions', 'Own voice analysis' (Figure 11). This may illustrate that the students had not yet developed an understanding of the metacognitive skills they employ during research and inquiry learning.

Nevertheless, based on the returned Research Skill Pentagons (see Figures 6-12), some of the students understood their instructions, and demonstrated their ability to determine some of the skills they use during research.

The exchange between John and the group who stated that they had ‘not very good ones’ highlighted the challenges educators face when introducing metacognitive frameworks into classrooms (Dajani, 2016). The student’s comments indicated they were not confident in their work, and that they were anxious about sharing their thoughts. Low confidence and anxiety may have inhibited their ability to cognitively engage through communication with John (Koehn, 2013). However, before being asked to communicate their work, the group was able to demonstrate their ability to question and hypothesise: their answer was excellent, and, in fact, very representative of the facet, question and hypothesise. If provided with more opportunities to exercise these skills, explicitly, students will improve (Koehn, 2013; McGowan, 2018; Rodríguez-Ardura & Meseguer-Artola, 2017). As a result, they may take more initiative in classroom discussions such as these

5.93 Lesson 2: MELT, Forgotten

Summative assessment tasks are critical for year 11 students who are completing the SACE because their entry into higher education relies on their results. The students’ disregard for the Research Skill Pentagon, upon realising it was not part of their next summative task, illustrated the priority given to summative assessments and its motivational effect (Trotter, 2006). In fact, unless explicit skill development is prioritised by teachers during planning, or incorporated into summative assessments, it is likely

that it will remain ignored (Dajani, 2016; Trotter, 2006). The lack of value students placed on the Research Skill Pentagon highlighted that they did not consider it useful. Whether it is in fact useful for secondary school students or not remains to be seen, however, frequency and routine use of a framework will be necessary in order to inculcate cognitive skill development (Dajani, 2016; Lucas & Smith, 2018). The incorporation of an explicit articulation of the metacognitive domains within summative assessments may support this.

5.94 Lesson 4: First Explicit Reintroduction of MELT

After two lessons where students worked on their research essays, I reintroduced the Research Skill Pentagon. At the beginning of the lesson I lectured about the RSP and how it related to their research essay. The students remained silent when asked to volunteer ideas about which skills they would use to complete their research essay, which signalled that they were not confident in explicitly articulating how the Research Skill Pentagon related to their task. However, I did not engage the students cognitively during the presentation, many of the students disengaged throughout, and subsequently they may have failed to learn. This sequence illustrated that the students had limited experience with explicit, metacognitive frameworks, and that employing strategies and frameworks for engaging students' cognitive and affective domains may be necessary to enhance engagement during lectures.

5.95 Lesson 5: Second Explicit Reintroduction of MELT

I reintroduced the Research Skill Pentagon more effectively in the fifth lesson. As I went through each facet one by one, I asked students about each how facet related to their research essay. By regularly questioning the students in order to make their thoughts about each facet visible, the majority remained engaged in the presentation, which illustrated the benefits of visible thinking as a way to encourage students to cognitively engage (D'Mello & Graesser, 2012; Ritchhart & Perkins, 2008; Torres, 2018; Whiteside, 2013). However, there were long silences after my questions, which indicated that it was difficult for students to generate ideas about which skills they would use for their research. This highlighted a gap in explicit, metacognitive understanding.

5.96 Lesson 7: Final Explicit Reintroduction of MELT

After my final presentation on MELT, it was clear that the students were responding to the Research Skill Pentagon more easily. Their answers were not precluded by long moments of silence, and I did not need to continually prompt them for answers. Therefore, students may have developed a clearer understanding of how MELT's cognitive facets connected to their learning. Having already practiced thinking out loud in relation to the RSP, their confidence appeared to have increased. This indicates that initial resistance to metacognition and making thinking visible can be overcome through frequency (Dajani, 2016).

However, despite the students' increased, explicit engagement with MELT, Sarah and Jimmy's attempts to complete the Research Skill Pentagon (see figure 13 and 14) illustrated that a comprehensive understanding of the cognitive skills required for research requires long term practice and slow development (Gresty, Heffernan, Pan, & Edward-Jones, 2015; Willison, 2018). For example, Sarah incorrectly identified 'planning of procedures' as an aspect of evaluate and reflect, while Jimmy was not able to identify any aspects of analyse & construct or evaluate & reflect.

It is worth considering other factors may have contributed to the students' increased engagement with MELT in this lesson. They were about to complete practical tests for which the students appeared generally excited, highlighting a link between positive emotions and engagement (D'Mello & Graesser, 2012; Maslow, 1943). Furthermore, this parallels the link I made between the students' enthusiasm for John's initial, enthusiastic questions about cooking popcorn and their engagement in that lesson. Moreover, by this time I had built a solid rapport with the vast majority of the students, which meant they may have been more relaxed in my presence. Therefore, the operations of the students' affective domain may have contributed to their engagement as well as any developments to their understanding of the cognitive domains.

Chapter 6: Conclusion and recommendations

6.1 Discussion

MELT and the Research Skill Pentagon

This study illustrated that each of the MELT facets was needed by year 11 secondary school students in the course of each chemistry lesson. Therefore, MELT is relevant and may support skill development in this context.

The students demonstrated particular competency in team management and communication skills. Based on their interactions with each other and the encouragement of their teacher, these skills appeared to be ingrained in the culture of the classroom. This highlights the benefits of regularly practicing skills in order to inculcate skill development (Dajani, 2016; Oliver & Venville, 2017). However, there were many examples where expediency in achieving results appeared to trump the application and practice of cognitive skills. This demonstrated that shifting from a focus on results to skill development may be difficult. In the long run, the priority given to results may inhibit the development of metacognitive capabilities which students may require for industry and higher education in the 21st century (Bandaranaike, 2018; Kivunja, 2014; Lucas & Smith, 2018; McGowan, 2018; Torres, 2018; Willison, 2018; Willison & O'Regan, 2007). Furthermore, in Amelia's example, shifting to a focus on skills may help her gain a sense of competence in literacy and lead to better engagement.

For the majority of the observations, the students operated on a the 'follow' stage of autonomy and frequently required support from teachers in order to engage their cognitive abilities and overcome challenges (Willison, 2019). Therefore, it appears that

it may be necessary to explicitly teach metacognition in order for students to practice their metacognitive capabilities and move higher into the levels of autonomy.

In the beginning, students found explicit interaction with MELT awkward, which reflects other attempts to introduce metacognitive frameworks such as visible thinking routines and the Cognitive Acceleration through Science Education (CASE) program (Dajani, 2016; Oliver & Venville, 2017). Students' long silences when asked to explicitly state the skills they used in undertaking tasks illustrated that the concept of explicit metacognition was foreign. However, students' performance in this regard improved gradually as MELT was continually introduced. For example, both Sarah and Ethan quickly provided answers as to how MELT related to their practical test in the seventh lesson, juxtaposing the long silences and lack of interaction in the introductory lesson. Although the efficacy of this improvement in relation to academic performance could not be measured in this research, it illustrates that a gradual development and regular practice of metacognition may support students' knowledge of and the deliberate regulation of their metacognitive domains (Bannister-Tyrrell & Clary, 2017; Dajani, 2016; Lewis, 2002; Willison, 2018).

6.12 The Affective Domain

Despite the fact that students explicitly expressed the affective aspects of their metacognitive states, such as anxiety, the regulation of these states was not observed. Not only does this highlight a need to improve students' knowledge and regulation of their affective states in order to be able to engage cognitively, it also highlights a gap in the MELT framework. In its current, published, form, MELT does not explicitly state the negative affective states that may inhibit cognitive engagement. However,

literature on flow helped illuminate the effects of the negative aspects of the affective domain in relation to student interactions with and about MELT.

The effect of student confidence and anxiety on student engagement was particularly evident. Confidence appeared to drive engagement, while anxiety appeared to drive disengagement. For example, Amelia demonstrated cognitive engagement in relation to MELT when testing substances with TED. In her example, she confidently recorded, questioned and verified results without hesitation or guidance. In contrast, Jimmy's hesitation when presented with the warning label on the bottle of hydrochloric acid indicated anxiety, which inhibited his cognitive abilities and left him unable to proceed with cleaning his metal scoop. It is possible to overcome the barriers of low confidence with the deliberate regulation of the metacognitive domains (Koehn, 2013). Therefore, the explicit teaching of metacognition may have direct benefits to student engagement, learning and achievement. In order to facilitate this, explicitly articulating and teaching these aspects of the affective domain may be necessary.

6.13 Visible Thinking Routines

Visible thinking routines were not observed as a regular practice in the two chemistry classes. However, when questioning was used, it often enabled students to cognitively engage, illustrating that visible thinking routines may support deeper cognitive engagement and metacognition in the classroom. However, they should be employed as well as frameworks such as MELT, which provide additional metacognitive descriptions that make the goals of visible thinking routines more explicit.

6.2 Recommendations of the study

- Educators should increase focus on explicit skill development in order to improve student engagement and general capabilities.
- Teachers should increase their knowledge and understanding of multiple metacognitive frameworks.
- Teachers should explicitly teach metacognition. However, this may only have a significant effect on students if this approach is adopted and supported by the entire teaching staff and leadership.
- A more comprehensive description of the affective domain should be incorporated within MELT, particularly in regards to the negative elements, in order to provide a better understanding of student engagement.
- If MELT is employed in secondary education, it should be incorporated and adapted into students' summative assessment pieces in order to make the explicit skill development a priority.
- It may be helpful to provide students with explicit strategies for regulating the cognitive and affective domain as they develop better metacognitive practices.

6.3 Recommendations for future research

- A broader and more comprehensive implementation of MELT in secondary education is required in order to better understand the nature of student interaction in relation to MELT.
- Implementing MELT at lower year levels, such as year 7 or 8, may reveal deeper insights into its relevance and efficacy in secondary education, due to

the fact that younger students are yet to fully establish and automate their research and inquiry practices.

- Understanding the efficacy of MELT may require long term research, therefore, in the near future studies should focus on students' current understanding of metacognition.
- It may be helpful to study the effect of research such as this on pre-service teachers. Developing a thorough understanding of MELT and the relevant literature, and experiencing lessons from a different perspective, may prove to have been useful to the researcher's own, future practice.

6.4 Limitation and biases of the study

The researcher may have been biased. He may have wanted the study to have had a positive effect on students and to produce useful outcomes. Furthermore, building rapport with students may have led to their interactions with the researcher being more positive, contributing to any biases in the study.

The students may have modified due to the presence of the researcher.

The study was conducted with only a small sample size, which may affect its transferability to other contexts.

There were only seven lessons from which to construct and analyse the data. The fact that frequency is an issue in relation to the implementation of metacognitive frameworks means that the study was unable to determine the efficacy of MELT in improving the students' skill development (Dajani, 2016; Oliver & Venville, 2017). Furthermore, by year 11, students have already developed and automated many of

the skills articulated by MELT. Therefore, any attempt to improve or develop these skills may have been futile considering the short period of time over which the study took place.

6.5 Conclusion

This study highlighted that secondary school teachers may benefit from employing a variety of metacognitive frameworks. With an understanding of MELT, flow, and visible thinking routines, educators may have the tools required to understand how, why, and when their students are cognitively engaging, thinking, and therefore learning (Csikszentmihalyi, 1975, 1991; Koehn, 2013; Ritchhart & Perkins, 2008; Torres, 2018; Willison, 2018; Willison & O'Regan, 2007). Furthermore, when students develop a knowledge and understanding of these constructs for themselves, they may benefit by reframing their education in a more meaningful way, lifting transferable skill development to the forefront of their vision. While results may always remain a priority, it is time that skill development is brought into sharper focus.

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Appendix

Data and analysis with codification:

Data and Analysis

Context (Still need to complete a more in-depth context to go before this section:

The chemistry classrooms sit side-by-side, separated by a wall which has a partition left open in order for the teachers and students to move between the rooms as needed.

The two classes are independant, but, since they are both completing same subject, they sometimes interact with one-another.

For our introductory lesson, John set up one of the classrooms so that both classes could sit in one classroom, which was unusual.

Lesson 1: Introduction to MELT

John, having mixed up his timetable, arrived a little early to class. Fortunately, this gave him a chance to arrange the desks and chairs in order for two chemistry classes to combine for their introductory MELT lesson. Soon, the students began to filter into the room. Some stood just inside the entrance, waiting for instructions about where to sit in their newly-configured classroom, while others seated themselves at the tables (A+C). Once instructed, the whole class organised themselves in groups of three or four around each table. The students appeared intrigued by the presence of John and myself, watching us closely (F+G). One student asked me, ‘are you from the uni?’ (F+G).

John and I took our positions at the front of the classroom, next to Joan. Dan was away, and his relief took a sedentary position at the back of the classroom. All students’ eyes were on John and I, silently and eagerly digesting the scenario. To begin the lesson, John and I introduced ourselves and the purpose of our visit. John then started up his PowerPoint

presentation. To begin, he asked the students, ‘why does popcorn pop?’. The students remained silent. John enquired, ‘Has anyone cooked corn in the microwave?’. No students responded, to which John reacted with surprise. He asked for a show of hands and repeated his question, ‘Has anyone cooked corn in the microwave’? No one raised their hand. John appeared perplexed that none of the students had ever cooked corn in the microwave. He enthusiastically exclaimed, ‘*One hundred percent* of students have not cooked corn in the microwave?!’ The students smiled and laughed, appearing to feed off John’s enthusiasm and his amazement at their lack of experience with corn and microwaves. He then asked for a show of hands, ‘who has cooked popcorn in the microwave?’ Everyone raised their hand.

John then introduced the first group task. In groups of 2-4, students were asked to brainstorm possible sources for popping energy when cooking popcorn in order to generate evidence for chemical change and physical change. I.e., why does popcorn pop? They were instructed to categorise their answers under two headings: Chemical Change and Physical Change, which was modelled on John’s powerpoint slide. For motivation, John advised that the group with the most ideas would be selected to read out their responses.

The students responded to their instructions with enthusiasm and went straight to work: In each group, students assigned an individual scribe (C+A O+M). In one group, the scribe used his laptop computer to draw up a two-columned table in Microsoft Word with the required headings, ‘Chemical Change’ and ‘Physical Change’ (O+M). Everyone else used their exercise books (O+M). Some used a ruler and a pen or pencil to draw a table that reflected the example on John’s PowerPoint presentation (O+M). One scribe wrote a more simplified example - they had written ‘Physical’ and ‘Chemical’ on a blank page in their exercise book, and I noted the absence of borders or lines to delineate the headings (E+R, O+M). There was a low murmur as students discussed their ideas in groups (C+A, F+G).

I visited a number of groups during this task to see how they were going. Most groups had only one or two items for each heading. I could see a few groups had very few ideas, so I prompted them with a question: 'what does popcorn look like before and after it pops?'. This helped generate further thought and discussion among students, and as a result they generated a few more ideas (F+G, C+A).

John called the class's attention back to the front and established which group had the most ideas. He then asked that group to read their ideas out loud, to which they obliged. John recorded their responses on the PowerPoint slide (See figure 1.) (C+A). At this stage, most students appeared to be listening, with their attention focused on the students who called out answers or on the board where answers were being recorded (F+G). After the first group's ideas were recorded, John asked for more ideas, which were offered periodically between moments of silence. They required a little extra prompting from John (C+A).

Once the students' ideas were recorded, John asked them to think about whether they would like to challenge some. Jimmy was the first student to volunteer to challenge an idea. 'Colour', he said, 'because 'it doesn't change' (E+R). He then argued that the white of the popped popcorn pre-exists on the inside, and simply appears when it is popped (A+S). Jimmy then challenged 'smell' and 'taste' using the same argument (E+R, A+S). After that, someone 'challenged' Jimmy's 'challenge' of taste, arguing that since there was a difference in the flavour of chicken before and after it is cooked, there must be a change in popcorn (E+R, A+S). At this, the class became a noisy babble as small discussions broke out amongst groups, presumably communicating their opinions regarding the challenges (E+R, C+A).

John called the class's attention back to the front of the room and asked the students to tell him which skills they used to complete the previous task. Jimmy called out, 'logic', because

‘we have to think about an idea to see if it makes sense’ (F+G, A+S). Another student offered, ‘experience’ (F+G). John asked the class to volunteer ideas about what experiences they already had that might have informed them during the task. Someone called out ‘science’, another offered ‘different energies’ (F+G). John asked, ‘any other knowledge we can draw on?’.

‘Cooking’, one of the students exclaimed (F+G).

After some further prompting by John, one student volunteered ‘communication’ (F+G). John asked for more ideas about communication: ‘Talking to one another, discussions’; ‘Expressing ideas’; ‘Debating’; ‘Cooperating’ (F+G). John asked the class to expand on cooperating. One student responded, ‘if someone said a basic word, [such as] ‘form’, then someone else might explain how the form changes. Would *this* be part of this?’ (A+S). John then asked the students to articulate another aspect of communication. The class remained silent for a few long moments. ‘What about what’s in front of you on your desks?’, said John.

‘Books’ (F+G).

‘Yes, but what is it in relation to communication?’

‘Writing’, one of the students replied (A+S).

John then prompted the students further to uncover the remaining skills they used for their task. After a few short periods of alternating silence and prompting by John, the students were able to identify the remaining skills; ‘evaluating your ideas: challenges the challenge’ (F+G, A+S); ‘organising: recorded the data, catagorise, separating’ (F+G).

John moved on to explain the ‘Research Skills Pentagon’, which took several minutes. Many of the students disengaged at this part of the presentation. Some took their phones out to check social media, while others stared blankly at their desks. Only a handful of students were focused on John or his presentation slide.

After describing the Research Skill Pentagon (RSP), John asked the students to offer an alternative question for the facet, ‘question and hypothesise’. Although none of the students immediately volunteered an answer, the call to action appeared to bring back the attention of the majority of those students who had disengaged: phones went back into pockets and all eyes were on John. The class remained silent for a few long moments. No one appeared able or willing to offer an alternative question.

John gave them one minute to create a question in their groups. The students began to discuss possible ‘question and hypothesis’ questions in a low murmur, while some began writing (E+C, C+A). After the minute was up, John asked if any of the groups would like to volunteer their question. The class remained silent. John then selected one group and asked them what they had come up with. They were silent for a moment, appearing reserved, until one student said, ‘ours aren’t very good’ (E+R). John asked them to give their ‘not very good ones’ anyway. ‘What are you doing and how are you going to achieve it?’, they responded (C+A). John congratulated them on their excellent response and wrapped up his presentation.

NP

Joan handed out an article about biofuels to each student, along with a list of points that students were supposed to address for their next summative task. Each group was also given an A3 copy of the RSP. Joan explained to her students that they should read the

article she handed out and summarise it. Upon receiving the handouts, a few of the students immediately began to read and highlight sections of the article (F+G, O+M). John explained to the students that they should analyse the information on the list of points they were given (figure 3) and categorise each point under one of the facets on their RSP. One student pair began to discuss where the information from the list would fit into the pentagon (F+G, A+C, E+R). A student who had begun to read and highlight sentences from the article continued to do this, completely disregarding the RSP (F+G, O+M). As I went around to various groups I found that most had managed to copy one or two sentences from their list and catagorise these under the headings on the RSP, but most students appeared to be stuck (A+C). I asked one group if they understood what to do. 'No', they replied. I approached two other groups who gave me the same response. Much of the talk I heard as I wandered through the room was off task. I began to help a few of the groups relate the points on their list with the RSP by asking questions such as 'what are you going to analyse?', 'what are you going to communicate?', 'what skills will you use for this point?'. Most students looked at me blankly. After a few short minutes it was time to pack up. John thanked the students for their participation and Joan wrapped up the lesson.

As they packed up, I asked one student about what he thought of the task he was given at the end. He said, 'it doesn't make sense', 'we went straight from other content to this topic' (E+R). I noticed he had not added any information to his pentagon, and had not shown any interest in reading the article.

The Research Essay:

As students entered the classroom they took up their usual seats and piled their textbooks and exercise books on their desks.

The classrooms were back to normal, and therefore the two classes were independent of each other.

I noticed two student pairs pull their A3, Research Skill Pentagons from between their pile of books and place them on their desks.

It was there they were left, ignored, perhaps there just in case.

NP

The students were tasked with reading the article on biofuels that was handed out in the previous lesson and to start to think about how they will address the list of dot points that was handed out in the previous lesson in order to write a research essay.

Early in the lesson, Jimmy brought his task sheet and Research Skill Pentagon to Joan.

'Do I need to keep filling this in, or just read the article?' (F+G, Q+H).

Joan advised him to just read the article for now.

At this stage most of the students were reading the article (F+G).

Some had begun to highlight various sections (F+G, O+M).

A few students had written headings into their exercise books and were copying information from the article underneath these (F+G, O+M).

Others were discussing the article article in pairs (E+R, C+A)

Yet, there were a number of students who sat at their desks chatting, or staring into space as if waiting for further instructions.

One of the students had already written a paragraph, and had included a citation at the bottom of her word document.

She told me she wanted to include the citation so that she could know where she had found the information.

I noticed it her citation was for a .gov website, and I asked her if she used Wikipedia as well.

'I would never use Wikipedia', she replied.

NP

I approached Amelia's desk and asked her if she had read the article yet.

She told me she had, so I asked her what she thought of it.

She was unable to tell me much about it.

'I tune out when reading', she said. 'I will probably have to read it again' (E+R, O+M).

NP

As I approached Sarah's desk, I noticed she and the student next to her had their maths methods textbooks open, and appeared to be doing calculations in their exercise books (F+G, E+R, C+A, O+M).

Sarah told me she was more concerned about her Maths Test, which was due to take place in the following lesson, and therefore she was studying for that (E+R, O+M).

NP

As the lesson was wrapping up, I noticed the student pairs who still had their Research Skill Pentagons on their desk, piled under a heap of exercise and textbooks.

I gestured to the RSP and asked them if it was helpful for this task. The students responded with a shake of their heads and a resounding 'no'.

Lesson 3:

In this lesson students students continued with their research task. They had been given a formative task sheet with two questions. One question asked them to summarise the article and the other asked them to make a comment on the credibility of the author.

For this task most of the students were working pairs, although this was not prescribed (C+A, O+M).

Many pairs had assigned one person to write, while the other searched for information from the article or the internet and read it out (F+G, O+M).

NP

I asked Sarah about what she thought about the credibility of the author.

She told me that she thought the author was fairly credible, but that he might be a little biased (E+R).

I asked her why.

She said the author came across as an environmentalist (A+C).

I asked a few other students the same question.

Most agreed that the author was credible, and they cited the many quotes and graphs from the article as evidence for this (E+R, A+C).

NP

As I approached Amelia's desk I noticed she had started to work on summarising the article.

She said, 'I'm not sure if I've summarised it right' (Q+H).

'Why don't you read it again to make sure?'

'No way am I reading it again. I'm struggling to focus.' Her head slumped to her desk (E+R). 'I'm feeling anxious because I'm falling behind in my Research Project' (A+C).

'*How* can you like English?' she asked me. She knew that I was a pre-service English teacher.

NP

I noticed Jimmy approach Joan with a question, 'Is there a task sheet yet?' he said (Q+H).

'Not yet, but it will be on Daymap soon'.

NP

Ted was working in a pair, and I noted that he had drawn a symbol which represented hydrogen on a page in his exercise book, an aspect that was not apparent on many of the other students' work (C+A).

His partner was using a mobile phone to find information that related to the points on their task sheet (F+G).

Ted transcribed the information as his partner read information from the website aloud (O+M).

I asked them what site they were using to find information.

Ted told me it was 'a university website' (E+R).

NP

I approached Sarah's desk as she was reading the article.

I noted that she had highlighted each of the 10 points on her task sheet in a different colour, and was now highlighting sections of the article with the colour that corresponded to each point (O+M, E+R, A+C).

NP

Joan handed out the summative task sheet, along with the relevant SACE achievement standards.

Some students began reading it right away, while others continued as they were, ignoring it (E+C).

NP

I noticed that Taylor had drawn the symbol for hydrogen just as Ted had. Alongside this she had also written its formula. I asked her whether the symbol was necessary.

'You don't have to draw the symbol, but it helps me understand it because it is easier to visualise.' She pointed to the symbol, 'You can see *this* is connected to that' (E+R, C+A, A+C)

NP

I returned to Sarah's desk. 'Which question will you answer first? I asked'

'The second question, because the author is biased and a bit of an environmental type' (E+R, A+C).

'So you want to ascertain his background before summarising his article?'

'Yes'.

NP

Meanwhile, Ted had begun highlighting the first sentence in each paragraph of the article. He subsequently read these sections aloud to his partner, who recorded them into his exercise book (O+M, E+R, F+G).

Lesson 4:

I noticed Jimmy had written 'Persuasive Argument' on the top of his page (O+M). I asked, 'oh, you're making a persuasive argument?'.

'Yeah, we have to. It says it on the assignment' (Q+H).

'Are you going to argue for or against biofuels?'

'We should use biofuels so we have more time to crack cold fusion' (C+A, A+C).

'Where are you going to get your information from?'

'I've already got some', he replied, as he pointed to his exercise book (O+M). 'But I need to find more, especially graphs' (E+R).

NP

I asked Nathan whether he thought the author was credible. He explained to me that he had discovered that the author was an 'award winner', which meant he was credible (F+G, A+C).

He had written the author's credentials as a list, below the question on the formative task sheet (O+M).

I asked him how he was going to reference the information he found. He told me that he was going to use a 'reference generator' from the school's intranet homepage (F+G, C+A). I asked him how he was going to search for information. 'Just google', he replied (F+G). He then explained there was a database he could access through the school's intranet but that he probably wouldn't use it unless he needed information to make his essay 'more credible' (E+R). Towards the end of the lesson, he had begun going through the information he had written in his exercise book and was adding it to a Microsoft Word document (O+M).

NP

I approached Sifa, who was highlighting sections of the article. I asked her why she was highlighting those sections in particular.

'I am highlighting key points in the text, which are usually at the tops of paragraphs', she said.

NP

In the final 10 minutes of the lesson, I presented the Research Skill Pentagon to briefly refresh the students on all of the facets. Many of the students lost focus during my presentation, and began to chat amongst themselves. I had to keep asking for their attention. After my presentation I asked the class what kind of skills from the pentagon were

they using while producing their research essay. The students were silent for a few long moments. I prompted them some more and offered a coupe of example. Finally, one student said ‘group work’. Then it was time to pack up.

Lesson 5:

I began the fifth lesson by reintroducing the MELT Pentagon. This time I had prepared a few slides about how the Research Skill Pentagon related to their research essay.

As I went through each facet, I engaged the students by asking them how they had used the skills on the pentagon so far. As a result, the students appeared to focus better than in the previous lesson.

For example, as I was going through the Organise & Manage facet, I asked, ‘Has anyone finished their essay yet?’. Sarah was the only student to raise their hand. ‘Did you use any tools such as calendars to manage your time?’, I asked her.

‘No. I just had a date in my head of when I wanted to finish it.’ (O+M).

‘Do you ever use a diary?’

‘No, I don’t need one’ (E+R).

‘Do any of you use a diary?’, I asked the class.

About half of the students said ‘yes’, or nodded in agreement.

A student pair stated that ‘couldn’t live without one’ (O+M, E+R).

After my presentation I asked for a show of hands to determine who had decided to argue for or against biofuels. The class was divided evenly (E+R). ‘Raise your hand if you think your opinion might change after you complete your research’, I said. About a third of the class raised their hands (E+R).

NP

As I made my way around the classroom, I overhead Dan encourage his students to share their research sources with one another. He told them it was important that if they found something useful that they share it with their peers.

NP

I approached Sifa’s desk. She had a word document open with ‘Combustion’ written as the heading. The rest of the document was blank. I asked her how the task was going. ‘Confusing’, she replied, ‘but Dan helped me out a bit’ (Q+H).

I returned a little later and found that she had made progress, with a neatly arranged graph in her word document that displayed the amount of energy required to produce various types of fuel (C+A, O+M).

NP

Nathan spent the first part of this lesson playing chess with his neighbour. I asked them who was going to win. Nathan told me he hadn't played before, and was just figuring it out as he goes along. I watched him try to move the horse across the virtual chessboard and fail (F+G). His neighbour told him that it moves in an L shape. Nathan tried again, successfully (A+S).

NP

I checked in on Amelia. 'How are you going to find the combustion demands for Ethanol?

'I'll have to do some more research', she replied (F+G).

It was about midway through the lesson, and she had spent most of this time playing 'MASH', a fortune telling game, to determine how her future would unfold.

NP

I revisited Nathan, who had finished his game of chess and now had a word document open, full of text, images and graphs. I asked him if he had just copied the text or whether he had re-written it in his own words. He said 'already in my words, but I don't know if I will use it all yet' (F+G, A+C, E+R). He told me he was worried that he had too much information, as the word limit was 1000 words.

NP

I asked Taylor how she was progressing. She told me the first question was the most difficult, which required her to find the energy required for the production and combustion of various fuels. 'She's found something useful', she said as she gestured to her friend (F+G). Taylor looked over her friend's shoulder to see what she had on her laptop and pointed to the text on the screen, 'that's the energy it takes in production, that's the energy it takes in combustion' (F+G). I asked Taylor where they had found the article they were reading. 'Jimmy sent us that link' (C+A, F+G). Jimmy was away sick, but had emailed them two articles he had found in his research. I asked Taylor if Jimmy's articles were helpful.

'The first link didn't work, the second link had some information but it didn't help with this question' (E+R). She pointed to the laptop screen again, 'I think the table is all we can use from this one' (E+R). I remained at her table making notes while she and her friend searched for more information. 'What's this one?', 'Have you found anything?', she asked her friend as they searched for information (F+G, Q+H). She studied one of the articles for a moment and exclaimed, 'By looking at the co2 emissions you can compare it, like maybe work out the percentage or something' (A+C, C+A).

NP

Meanwhile, Sifa was struggling to find information about the emissions in the production of various fuels, and she told me she did not know how to calculate them herself (E+C). I asked Dan for clarification about the calculation of the emissions. He told me 'they haven't done that bit yet', referring to the formulas for calculating emissions, 'but they can find the information online'.

I approached Sifa later in the lesson to see how she was going. She was using virtual sticky notes on her monitor to enter the due date for this assignment (O+M). I asked her what she thought of chemistry. She said, 'it's too hard', 'I am going to drop chem' (E+R, A+C). She

had previously told me that in her previous school she did not do any research or essay writing. She simply prepared for and sat for exams.

NP

Like Sifa, many of the students were stuck trying to find the data on co2 emissions. Nathan was one of these. He showed me his google search, which stated 'what energy is involved in getting petrol' (F+G). He had visited a couple of articles from the results list, but found they were general in nature, and did not include the data that he needed (E+R). I encouraged him to modify his search terms to make them more specific. He then typed into the search bar, 'how much energy needed for production of petrol' (E+R, A+C, F+G). This impacted his results significantly, and he was able to discover the data he needed.

THE PRAC:

Lesson 6:

To begin the lesson, Joan handed out the task sheet for the students' formative task.

In Dan's classroom, he began the lesson by providing his students with a brief presentation about how to calculate the percentage of nitrogen from a chemical formula for fertiliser. When he was at the final stages of his calculation he asked for a volunteer to calculate the percentage based on the numbers he had presented. I noted that Amelia was particularly engaged in his instruction. She rushed to get her phone out to make the final calculation (A+C).

NP

Sarah began the lesson with her text book open and her worksheet on her desk. She had begun searching for information in her books that would help her fill in the blank table (F+G). She required information such as flame colour and melting temperature for a number of substances. Suddenly she stopped searching and asked her friend, 'don't they have a diagram?' (Q+H). She got up and went to the other classroom and returned a few moments later. 'It's blood red. I saw it on the poster', she said (F+G).

Having witnessed this, Joan reminded the rest of the students, 'there is a flame chart in the other classroom'.

As I was taking notes, Sarah asked me, 'do you know if carbonate is a metal?' (F+G).

'I don't know', I replied. 'How are you going to find out?'.

'Google' (F+G).

NP

Later, Sarah was attempting to determine the difference between a covalent lattice compound and covalent molecular compound. She searcheed in her text book and asked Joan, 'does it look like this?'(F+G).

'You need to look up the diagrams. That's another resource', Joan replied.

Sarah then searched her text book for more diagrams, but she still seemed unsure whether she had the right information. Joan drew an example of each compound structure to show her the difference.

NP

Joan then asked the students, ‘what do we need for something to be conductive?’.

The students remained silent. After a few moments Joan provided the answer. ‘I need you to start thinking about how you will find out if your ionic compounds are conductive or not, either as solids or liquid’, she instructed.

NP

Amelia told me about her English assignment, which I referred to in an earlier analysis.

NP

I noted that Taylor and Jimmy were communicating with each other about the task. They were working through their textbooks to find the information they needed to fill in their table. ‘Is that the same thing that is here?’, Taylor asked Jimmy (A+C, C+A). Jimmy read some of his answers from his text book, while Taylor transcribed them into hers. She used her calculator as if to practice the calculations and verify Jimmy’s answers (E+R, A+C).

NP

Amelia looked over to Ted’s task sheet, which which had a completed table with all the information about the substances. She asked him, ‘how did you know that?, referring to the section about melting points (F=G).’

‘Easy when you look at the melting points’, he replied (A+C).

Dan approached Amelia as she was completing her table by copying Ted’s answers. ‘How did you know that?’, he asked her, suspecting that she might have copied.

‘I copied from his’, she replied.

‘How did you know he is correct?’

‘You just gotta hope’. Dan encouraged her to look for the other answers by herself, and advised her that she should be able to find the information in the textbook. Amelia opened her textbook and searched for the information (F+G). It took her some time, but eventually she found a graph which had the information she needed. ‘I haven’t been listening all year’, Amelia confided after Dan had moved far enough away from her desk (E+R). (WHAT was different about today then? Cause she did listen at the start.

NP

As I approached Sarah’s desk she was discussing which tests she and her partner which tests might not be necessary in completing the table of information about the substances. ‘If

we've got the flame colour, do you need to test this?', she said, as she points at the table (E+R, A+C).

Joan instructed the class, 'start thinking about what to test first'.

In went to the other classroom. Amelia was drawing a cartoon man on the whiteboard.

I approached Taylor and Jimmy again and asked, 'what are you going to test first?'

'Flame test first', Taylor replied.

Jimmy added, 'might be able to do a soluble test instead.' (E+R).

Lesson 7:

Today the students were tasked with a practical test.

I began this lesson with another brief presentation on the six facets of the RSP and how they related to their task. As well as the presentation, I handed out a copy of the RSP to each student which had reflective questions on the back.

I first presented the facet Question and Hypothesise, and subsequently gave the students one minute to create a question or hypothesis for their task in pairs or small groups, and to write their response on the RSP. As I wandered around the room, I found that many students were just discussing other things, off task, and many made no attempt at filling in their sheet with an answer. Half of the students had left their pens and pencils in the other classroom.

After one minute, I called the students' attention back to the front and asked for answers. Sarah answered first, (NEED TO FIND copy on blue hdd), while Jimmy answered second. I noted that there were no long silences between answers.

I touched on the other facets more briefly with questions about how each facet related to their task. Students provided a variety of responses (some of which I have to find from the PTT), which appeared to be more forthcoming than previous attempts to engage them explicitly with MELT.

Before I finished, I asked the students to answer the reflective questions once they had completed their prac.

NP:

For the practical tests, students were to test the flame colour, conductivity, and solubility of four unlabeled, white substances and record their results in order to determine which substance was which. I focussed on two student groups throughout the prac: Amelia and Ted, and Taylor and Jimmy. Towards the end of the lesson I followed up with Sarah briefly.

Taylor and Jimmy:

As I approached Taylor and Jimmy they were discussing what they would test first. 'Let's do the flame test first', says Taylor.

‘But we won’t be able to do soluble for this one’, Jimmy points out, as he point to one of the substances on his task sheet (A+C).

I asked Taylor why she wanted to start with the flame test. ‘I want to do the flame test first because it looks good and I can see the flame’s colours’ (E+R).

Jimmy tells me, ‘but it’s more about the conductivity than the flame colour’ (O+M, E+R). He had determined that he could reduce the amount of tests they did if they started with solubility tests. Amelia seemed to get her way in the end. She opened one of the bottles containing white powder, and Jimmy took a small scoop and placed it into the flame of their Bunsen burner (F+G). The flame glowed bright red. I noted that behind the Bunsen burner, Taylor had set up her phone to record their experiment in video (F+G, A+C, C+A). I asked her what the video was for. She told me it was for a time-lapse.

NP

Once they had finished their first flame test, Jimmy approached a desk where there was a bottle of hydrochloric acid and a jar full of test tubes. At this station students could clean their scoops so that they were not contaminated by the previous substance. I watched him as he stood still for a few moments before the cleaning station, and then said, ‘it says dangerous’. The bottle is labelled as ‘dangerous’, in red (F+G, E+R). It was clear Jimmy did not feel comfortable touching the bottle. I picked up the of the bottle, which had a dropper attached, and then replaced it. Jimmy then picked it up, put a few drops of hydrochloric acid in a test tube, and began to clean his scoop.

Once back at his Bunsen burner, Jimmy began to burn the next substance (F+G). Danwas watching. ‘It should be going purple’, Dansays. The flame colour did not change. Jimmy took the substance from the flame and cleaned the scoop a second time in acid (A+C). On this attempt the substance glowed purple (F+G).

I noted that Taylor had recorded their flame test results in a neatly drawn table, which mirrors the table on their task sheet (O+M).

NP

After completing all flame tests, Taylor and Jimmy could finally prepare for the soluble and conductivity tests. Taylor held up a test tube and asked Jimmy, ‘why is it yellow’? (F+G).

‘Because we’ve used it. It’s hydrochloric acid’.

Jimmy then places metal prongs into each bottle containing a white substance as a solid in order to test their conductivity. I noticed that was the only student to test the substance’s conductivity as solids. All other students tested them as solubles.

NP

Towards the end of the lesson I saw Jimmy had begun to write his testing procedures as required by his task sheet, while Taylor’s remained blank. She appeared to have no interest in completing it during the lesson. I asked her if she would fill it in. ‘I’ll do it for homework’, she replied (O+M).

‘I’ve never seen you do homework’, said Jimmy.

‘That’s because I haven’t needed to’ (A+C).

‘He says we do, we need to’, Jimmy stated (E+R).

‘I’ve done up to the last question’, Amelia replied, referring to her textbook.

NP

At Amelia and Ted’s workstation, Amelia opened a bottle with a white substance. Ted scooped a small amount and placed it into the Bunsen burner’s flame (F+G). It burned bright red. Ted asked Amelia, ‘wanna take a photo?’ (F+G).

‘Yeah’. Amelia retrieved her phone from her bag and took a photo (A+C). I asked Ted whether the photo was to record their results or for social media. He told me with a cheeky smile, ‘it is for our results’. We already know what colour it’s going to be’. While Ted burned substances, Amelia recorded the results on her task sheet (O+M). She did not draw a table like Taylor did, but instead spaced the results evenly so she could differentiate between the tests (O+M).

Once their flame tests were completed, Amelia began to compile the equipment needed for the conductivity tests. ‘Where does this go?’, she asked Ted, holding a red and black cables (F+G). She carefully studied the battery and fit the cables into the corresponding red and black sockets (F+G, A+C). Dan was standing by. ‘Test the battery first’, he said. Ted took the device from Amelia and squeezed the two metal prongs together (F+G). The light globe turned on.

‘What have we gotta do?’, asked Amelia.

‘We gotta put in these and then test them. I’ll get a peg’, Ted replied. Ted placed water into a test tube and dissolved a small scoop of one of the substances inside. He placed the metal prongs in the water and the light globe lit up (F+G). ‘Bubbling, turning yellow’ he said (F+G). Amelia recorded his observations on her task sheet.

‘Anything else? Is it getting hot?’ Amelia asked (F+G).

‘No’. Ted paused and watched the test tube closely. ‘Orange chunks’.

Once they finished the test, Amelia asked, ‘was it sodium chloride?’.

‘Yeah. Wait.’ Ted paused. ‘Sodium carbonate?’ (Q+H) Ted looked at the four bottles of white substances on his table, but appeared unsure which one he placed in the test tube.

‘Are you sure?’ Amelia asked (Q+H).

‘No’ (E+R).

‘Wanna do it again?’ (Q+H)

‘Yeah. Did you write down what we saw?’ (Q+H).

‘Yes’.

NP

After completing their tests, Ted recorded the list of equipment he used for the tests in his task sheet. Meanwhile, Amelia appeared to be relaxing, with no regard for her task sheet. I noted they were the first student pair to complete their tests.

Writing english vs writing science? Amelia enthusiasm for writing and recording her observations… she appeared to be cognitively engaged in this. Intresting.

Sarah:

Although I did not observe Sarah completing her tests, I caught up with her towards the end of the lesson. She had successfully tested and completed the first able, and was subsequently given two unknown substances to test. I asked her how she went with those two.

‘Good. We had to test this one first because we couldn't test the flame colour of that one. In the first flame test I saw as soon as it clumped together I knew it was glucose, because that’s what happened when I tested it before, which eliminated one substance. Then there was one liquid substance on our list so I knew it wasn’t that one, and that left these two’. She pointed to two of the substances on the table. Then I tested this one and saw the flame colour pink, which confirmed it was potassium chloride (or what ever it wsa).