Investigating the Impact of a Flipped Classroom Approach for a Teacher and Students in Year 9 in the Topic of Linear Equations

Andrew Paul McAlindon

ORCID ID: 0000-0002-3655-457X

Submitted in partial fulfilment of the requirements for the degree of

Doctor of Education

Melbourne Graduate School of Education
The University of Melbourne

April 2020

Abstract

Access to technology in secondary education has increased substantially over recent years, affording new opportunities for teaching and learning. A technology-enabled flipped classroom is one approach that can be implemented when technology is readily available. This research investigated the impact and efficacy of a technology-enabled flipped classroom in secondary mathematics for the students and teacher. Students' understanding of solving linear equations, their attitude to mathematics and experiences in the flipped classroom were investigated. The experiences and perspectives of the teacher in implementing a flipped classroom for the first time were also explored. Comparisons between two teaching approaches (flipped and nonflipped) were made through a 4-week linear equations topic in two separate Year 9 classes taught by the same teacher. A quasi-experimental design with a control (nonflipped, $n = 23$) and experimental (flipped, $n = 22$) group was utilised. Students' understanding of solving linear equations was determined through pre- and post-testing using online diagnostic assessments (SMART tests; Specific Mathematical Assessments that Reveal Thinking). A pen-and-paper (delayed) assessment was also provided to students 3 weeks after the topic, which paralleled the items from the SMART tests. Students' attitudes were gathered by pre- and post-topic surveys using a prevalidated instrument (Mathematics and Technology Attitudes Scale). An open-ended student survey furthered insight into student experience and perspective for the flipped group. The teacher's experiences and perspectives were gathered through three semistructured interviews before, during, and after flipped classroom implementation. Qualitative analysis showed similar improvement to student understanding in the flipped and nonflipped groups directly after the linear equations topic. Delayed testing revealed a greater retention of understanding in the flipped group. Quantitative analysis of student attitude found no significant difference ($p > .05$) for all subscales measured between the flipped and nonflipped groups before and after the linear equations topic. Thematic analysis of student responses in the flipped group revealed favourable perceptions of the flipped classroom for most students. The teacher experiences highlighted a favourable perception of the flipped classroom, highlighting an increased capacity to support student needs, with reduced stress in the face-to-face classroom. The benefits of the flipped classroom were noted to have come at the expense of substantially increased planning time for the teacher. The results of this mixed-methods research provide insight into the efficacy of a flipped classroom in an Australian secondary mathematics classroom context, with practical implications and recommendations for future research outlined.

Declaration of Originality

This is to certify that

(i) the thesis comprises only my original work towards the DEd;

(ii) due acknowledgement has been made in the text to all other material used;

(iii) the thesis is fewer than 55,000 words in length, exclusive of tables, maps, bibliographies and appendices.

____

Andrew Paul McAlindon

Preface

This thesis has been formatted to adhere to the standards in the American Psychological Association's *Publication Manual* (Seventh Edition; 2020).

Pam Firth (Detail Devil Editing Services) provided professional copyediting and formatting, and her recommendations are according to the guidelines laid out in the university-endorsed national *Guidelines for Editing Research Theses* (Institute of Professional Editors, 2019).

Acknowledgements

The completion of this research has been made possible by the support of my family, friends, and colleagues. I would like to thank my parents Michael and Carolina who have provided ongoing support and encouragement in all aspects of my studies. You are both my first, and best teachers in life. I am also fortunate to have had the unwavering support of my wife Liz who has enabled me to spend an uncountable number of hours away from family to allow me to plan, conduct, and write this research.

I would also sincerely like to thank my primary supervisor Dr Lynda Ball for her ongoing support, encouragement, and guidance throughout all aspects of this research. The wealth of knowledge shared, along with the attention to detail provided in all aspects of the research, have allowed me to further develop my understanding of educational research. I would also like to thank my secondary supervisor Associate Professor Shanton Chang for his feedback and suggestions throughout the research. The contribution of knowledge and support from both supervisors has guided me in being able to complete this research, and I am sincerely appreciative of that.

I would like to thank Associate Professor Suzanne Rice who provided valuable feedback, insight, and encouragement as chair of my research advisory committee. I would also like to thank Mr Cameron Patrick, statistical consultant in the Melbourne Statistical Consulting Platform at the University of Melbourne, for his guidance and advice on the quantitative statistical analyses within this research.

I would also like to thank Catholic Education Melbourne, the principal, the teacher participant, and all student participants for their willingness to be involved in this research. Finally, I would like to acknowledge the support provided to me through the Australian Government Research Training Program Scholarship and Melbourne Research Scholarship, without which this research would not have been possible.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AES	addition equation solution
AE	affective engagement
AF	algebraic fraction
BE	behavioural engagement
BES	bracketless equation solution
CK	content knowledge
CT	confidence with technology
DEAG	Digital Education Advisory Group
DEEWR	Department of Education, Employment and Workplace Relations
DER	Digital Education Revolution
EVT	expectancy-value theory
FLN	Flipped Learning Network
ICT	information and communication technology
MTAS	Mathematics and Technology Attitudes Scale
MC	mathematics confidence
MT	mathematics with technology
MKG	misconceptions and knowledge gap
PCK	pedagogical content knowledge
PK	pedagogical knowledge
RES	reverse equation solution
STEM	science, technology, engineering, and mathematics
SE	simplification error
TPACK	technological pedagogical content knowledge
TPK	technological pedagogical knowledge
TC	technology content

TK	technology knowledge
SMART	Specific Mathematics Assessments that Reveal Thinking
VCAA	Victorian Curriculum and Assessment Authority

Chapter 1.

Introduction and Background

The 21st century has ushered in an increased prevalence of, and access to, technology for students and teachers alike, both inside and outside physical classroom spaces (Groff & Mouza, 2008). This, in turn, has presented challenges for educators that call for “fresh thinking about what is taught, how it is taught and why it is taught” (Moyle, 2010, p. 5). The Australian Government’s Digital Education Revolution (DER) report (see Digital Education Advisory Group [DEAG], 2013; Department of Education, Employment and Workplace Relations [DEEWR], 2013) highlighted the need for integration of learning with digital technologies, claiming, “more needs to be done if the teaching profession is to capitalise on the potential value of technology” (DEEWR, 2013, p. 7). Alongside this claim are those made through reviews of policy and practice relating to the use of digital technologies in Australian schools (e.g., Moyle, 2010), which signified the importance of reconceptualising pedagogy to integrate technology effectively.

The flipped classroom is one pedagogical approach that can provide teachers with the opportunity to convey aspects of their instruction via digital technologies (see Section 1.1). The flipped classroom is an “instructional model, in which activities traditionally conducted in the classroom (e.g., content presentation) become home activities, and activities normally constituting homework become classroom activities” (Akçayır & Akçayır, 2018, p. 334). The content presentation generally utilises digital technologies through the conversion of instruction into video resources before the student enters the class (Lo et al., 2017).

Flipped classroom success has been reported anecdotally in educational settings through claims of improved student achievement and attitude (Bergmann & Sams, 2009). The DER program's mid-program report (DEEWR, 2013) also suggested the flipped classroom to be a potential approach for Australian classrooms to enhance opportunities for student learning through technology in secondary school education. More recently, a growing emphasis on data-driven research has validated these anecdotal observations (e.g., Lo et al., 2017; Muir & Geiger, 2016). However, the improvement to student achievement and attitude has not been universal, with some research indicating no difference in student achievement with a flipped pedagogy (e.g., Jensen et al., 2015; Kirvan et al., 2015). The inability of research to establish a universal impact of the flipped classroom has been attributed to differences in its implementation, and these are discussed further in Chapter 2. There is also no universal standard for flipped classroom implementation (explored further in Section 1.1), and this inconsistency may too influence its reported effectiveness.

At present, research investigating the flipped classroom is dominated by higher education or postgraduate environments that span a multitude of subject areas (Akçayır & Akçayır, 2018), and so it is difficult to generalise findings to specific subjects at a secondary school level. A recent meta-analysis (Låg & Sæle, 2019) suggested a "somewhat blurry picture" (p. 3) of the current literature pertaining to the flipped classroom. This meta-analysis revealed a varied impact for the flipped classroom dependent on discipline, which could therefore present further issues in attempting to generalise the results of other research from other subjects.

The effective integration of technology within teacher pedagogical practice has been long reported hindered by teacher adoption and comfortability in use (e.g., Sherwood, 1993). Research has reported the challenges faced by teachers attempting to adopt new technology in their curriculum (e.g., Kearney et al., 2018), highlighting that integrating technology within curriculum delivery can be problematic. The flipped classroom literature also demonstrates challenges for teachers to overcome in managing technology for content delivery. These challenges include an increased need for technology competency and increased workload demands for planning and implementing a flipped classroom (Akçayır & Akçayır, 2018).

The integration of technology within a flipped classroom calls for teachers to integrate subject content, pedagogical knowledge, and technological knowledge. Mishra and Koehler (2006) described this overlap as “technological pedagogical content knowledge” or TPACK. While the TPACK framework is not directly linked with flipped classroom research, it exemplifies the demands placed on a teacher in the implementation of a technology-enabled flipped classroom. The TPACK framework describes the knowledge requirements that are incumbent on teachers to teach subject content effectively using technology, and this is discussed further in Section 1.4. While the effective integration of all aspects of TPACK could theoretically produce the technology-enabled flipped classroom environment, the dearth of flipped classroom literature at the secondary school level provides limited insight to this integration. Further, it remains to be understood if students in the secondary mathematics classroom could benefit from viewing teacher explanations on demand, outside of their regular classroom environment. In particular, it is pertinent to understand if the same advantages and affordances with the flipped classroom in postgraduate settings are able to be observed with a younger audience, given the potential differences in attitude, culture and motivation between these two settings. Additionally, with most research focusing attention on “achievement” (measured by raw score calculations of correct/incorrect responses), there is little indication of the influence of the flipped implementation on student understanding (i.e. mastery of skills or concepts with delineated levels of difficulty); the current study provides insight into this aspect. This is particularly important in mathematics, as mastering a skill or concept from one topic or lesson, can often be the lynchpin for success in the next. This doctoral research sought to investigate the impact of a technology-enabled flipped classroom approach in Year 9 mathematics. The research compared students’ understanding of linear equations and their attitudes when learning mathematics in two classes, taught by the same teacher, where the experimental group was taught using a flipped approach.

1.1 Flipped Classroom: Overview of Components

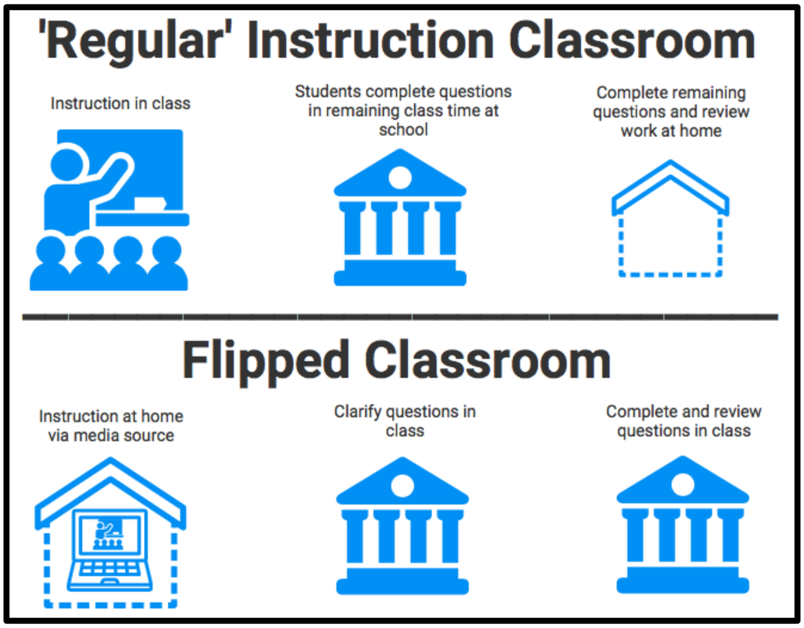
Classroom lessons can be considered as having two main components: an out-of-class and an in-class component. These two components differ in the timing and location of the activity, with the out-of-class component occurring asynchronous to the in-class component (which is usually a scheduled face-to-face lesson). For a regular classroom lesson, the in-class component is generally used for explaining content and worked examples, and the out-of-class component is for students completing homework questions or tasks set by the teacher. A flipped classroom “flips” this paradigm, with the content and worked examples given as homework (out-of-class component: a pre-class activity), and the questions or tasks set by the teacher completed in class. This interpretation is consistent with the definition offered in the literature, with Akçayır and Akçayır’s (2018) review defining the flipped classroom as a “new and popular instructional model, in which activities traditionally conducted in the classroom (e.g., content presentation) become home activities, and activities normally constituting homework become classroom activities” (p. 334).

However, despite the concept’s commonalities in the literature, researchers have implemented flipped classrooms in different ways. While its more recent popularisation has been credited to the anecdotal work of Bergmann and Sams (2009, 2016), who used videorecordings and annotations to transfer their regular chemistry lectures to an online format, there is no global definition or practice by which all flipped classrooms operate through the use of technology of video lectures (Love et al., 2014). Lo et al. (2017) highlighted this particular point in their synthesis of flipped research in mathematics education, reporting no standard pedagogical approach to its implementation. Lo and Hew (2017) showed the wide-ranging pre-class activities reported in flipped classroom literature, including watching videos, reading articles, viewing presentations, and reading a textbook. Furthermore, myriad differences between in-class activities are reported in flipped classroom literature. For example, flipped classroom in-class activities include teachers providing students with additional time for independent practice, active-learning activities, textbook review work, student presentations, small-group work, group discussions, and targeted focused learning on previously identified problems (Lo & Hew, 2017). The wide-ranging differences among the types of pre-class activities in research using the term flipped classroom make it difficult to determine its true efficacy. For example, Jensen et al. (2015) found no difference in student achievement and satisfaction between flipped and nonflipped classrooms when both utilised the same active-learning style in class. Their study, which sought to determine flipped classroom effectiveness by controlling for in-class components between flipped and nonflipped groups, highlighted the caution that should be taken when interpreting and comparing flipped classroom research that does not have the same in-class activities. Any differences in pre-class and in-class activities among research studies could account for the reported discrepancies concerning student outcomes and the overall efficacy of the flipped approach, and this is analysed and discussed further through Chapter 2.

While the differences in pre-class and in-class activities are prevalent in the flipped classroom literature, Akçayır and Akçayır's (2018) definition shows that the general structure of a flipped classroom is constant; students access instructional content (that would have otherwise been presented through class) in their own time. In this doctoral research, the definition of a flipped classroom is consistent with Akçayır and Akçayır's (2018) definition given earlier. Furthermore, in this research, the pre-class activities were video resources developed by the teacher and made available to students online (see Section 3.7.1), constituting the "technology-enhanced pedagogy" as described by Lo et al. (2017). However, given the in-class activities were at the teacher's discretion and were intended to be the same as her regular approach, it was not fitting to use all of Lo et al.'s flipped classroom definition, which required "integrated use of assessments, mini-lectures, individual problem-solving, and small-group learning activities in the classroom" (p. 53). Figure 1.1 simplifies the concept of the flipped classroom in this research.

Figure 1.1

A Simplified Comparison of a Regular Instruction (Nonflipped) and a Flipped Classroom



1.2 Student Understanding and Pedagogical Considerations: Solving Linear Equations

This section provides an overview of the mathematics curriculum in the state of Victoria, Australia, to provide general insight to the structure of teaching and learning algebra in Australian schools. The difficulties experienced by students in understanding algebra is then discussed, with particular attention given to linear algebra given it was the focus of this doctoral research. Finally, the link between student understanding and the teacher's pedagogical approach is established to highlight the role a flipped classroom can have in addressing student understanding of linear equations.

Education is state based in Australia, with the mathematics curriculum in Victoria prescribed for all students from Foundation (i.e., the first year of primary school) to Year 10 (Victorian Curriculum and Assessment Authority [VCAA], n.d.). In the curriculum, there are three strands: "Number and Algebra" , "Measurement and Geometry", and "Statistics and Probability". The Number and Algebra strand describes the skills and knowledge that students should demonstrate for each year of learning between Foundation and Year 10 within that strand. There is no prescribed approach to how the curriculum should be taught, and thus, the onus is on the individual school and teacher to determine how each strand will be taught to achieve the curriculum's goals. Solving linear equations is part of the Number and Algebra strand at Year 9 in the Victorian curriculum.

The difficulties that students experience when attempting to apply strategies to solve algebraic equations is well documented in the literature (e.g., Booth, 1988; Chick, 2009; Colton & Smith, 2014; Herscovics & Linchevski, 1994; Linsell, 2009; Stacey & MacGregor, 2000), and these are discussed in Chapter 2. Solving algebraic equations requires students to think differently to how they had otherwise thought when solving equations in purely arithmetical situations. Kieran (1981) showed the notion of equality between two sides of an equation to be poorly understood by elementary- and high school-aged students. Her work demonstrated students seeing the equals sign as an operation, rather than as representing the notion of equality between the two sides. Filloy and Rojano (1989) expanded on this research, hypothesising lines of evolution to exist when students attempt to move between arithmetical and algebraic language. Through examining student responses to a range of linear equations, they found that while some students could solve some equations through simple, one-step mental calculations, other equations required multiple steps to produce a solution. These additional steps, which brought about increased complexity, required a non-arithmetical (or algebraic) way of thinking. Linsell (2009) also considered the solving of linear equations to be hierarchical, with methods requiring non-arithmetical processes representing the most complex of equations for students to solve, and this hierarchy, along with the differences in thought processes required to solve complex equations, are explored further through Section 2.1 of the literature review.

The transition in thinking required to solve more complex linear equations calls for different methods of solving to be utilised. Kieran (1992) outlined a list of seven discernible methods for solving equations, each of which ranged in their procedural or conceptual complexity (see Section 2.1.1 for further detail). A student's reliance on particular methods to solve linear equations is highlighted through the literature, with the method utilised often being indicative of student understanding (Stacey et al., 2013a). Several studies since Kieran's (1981) and Filloy and Rojano's (1989) work have continued to emphasise the importance of students being able to recognise the relational or equivalence nature of the equals sign to solve algebraic equations (e.g., Kieran, 1992, 2004, 2013; Linsell, 2009; MacGregor & Stacey, 1997; Ronda, 2009; Welder, 2012).

Student understanding relating to solving algebraic equations can be impacted by pedagogical approaches employed at the classroom level (e.g., Drijvers et al., 2010; MacGregor & Stacey, 1997; Lewis & Blunk, 2012; Molina et al., 2017). Therefore, to assist students in using appropriate solving methods, teachers need to ensure understanding has been scaffolded through effective pedagogical approaches and techniques. Opportunities for students to solve a variety of linear equations should be embedded within the teaching and learning program to build their understanding. While debate has long raged over the efficacy of direct instruction and inquiry-based learning as an approach to teaching (Star & Rittle-Johnson, 2008), the flipped classroom can add a further point of deliberation to this debate given the flipped classroom has the capacity to incorporate aspects of both direct and discovery-based learning (explored further through Chapter 2). The role of the flipped classroom as a pedagogical approach for assisting the development of student understanding in linear algebra is a relatively unexplored area in secondary school education.

1.3 Student Attitude in Mathematics

While student understanding is one measure of student outcomes in the classroom, another equally valid measure is student attitude (or affective response), and this section highlights the importance of student attitude and its relationship with achievement in mathematics at a secondary school level. McLeod (1992) highlighted the importance of affect in learning mathematics, claiming through a summary chapter in the *Handbook of Research on Mathematics Teaching and Learning*, "Mathematics education research can be strengthened if researchers will integrate affective issues into studies of cognition and instruction" (p. 575). Through his review, McLeod's contention is that researchers who fail to gather data on affective responses in mathematics education are missing an important characteristic of student performance. This contention is built from the volume of research demonstrating the intense affective responses that are likely to result when students encounter what they consider to be nonroutine problems. The importance of student affective responses, collectively termed "attitude" in this doctoral research, continue to be reinforced decades on from McLeod's initial work (e.g., Di Martino & Zan, 2015), highlighting the critical influence student attitude can have in learning mathematics.

Shortly following McLeod's work, Ma and Kishor (1997) highlighted little consensus in the literature with regard to the relationship between attitude towards mathematics and mathematics achievement, delving deeper in an attempt to better understand this relationship. Their meta-analysis of 113 studies (involving 59,925 students) revealed statistically significant causal relationships between students' attitude towards mathematics and achievement in mathematics. More recent empirical evidence weighs in on the significance of attitude in mathematics, with a large-scale empirical investigation (N = 1,090 students) demonstrating changes to student attitude and subsequent achievement in mathematics in response to changing the pedagogical approach (Boaler et al., 2018). The link between attitude and achievement is further reinforced through theoretical frameworks such as the expectancy-value theory (EVT) in education (see Eccles, 1983; Eccles & Wigfield, 2002; Wigfield & Cambria, 2010; Wigfield & Eccles, 2000). EVT demonstrates the importance of attitude (e.g. confidence and motivation) through positing that student academic achievement and continued interest in a subject is directly influenced by aspects of student attitude.

Given that attitude changes and achievement are linked through EVT, there is good reason to better understand changes and/or influences to attitude as they may ultimately impact academic achievement. Further, given the link between student attitude and continued interest in a subject, it would be worthwhile to ensure changes to attitude are monitored with regard to new pedagogies to ensure any continuing interest in the subject is not diminished. This point is particularly pertinent in the secondary school context as mathematics is compulsory only until Year 10 in the Victorian Curriculum. It is important that future enrolment in mathematics is not impacted through a diminished attitude brought about through pedagogical approach in the compulsory education years.

Given a flipped classroom can call for a change to a teacher's regular instructional pedagogical approach to teaching and student learning, there is potential to impact the affective domain. Research into the flipped classroom has focused on the affective responses of students, with conflicting results. While some studies have reported higher levels of student satisfaction with their learning (Deslauriers et al., 2011; Love et al., 2014; Muir & Geiger, 2016), others have demonstrated decreases in student satisfaction (Strayer, 2012) or a neutral impact (Johnson & Renner, 2012). This range of positive, negative, and neutral findings surrounding student affective responses in the flipped classroom are explored further through Chapter 2 to better understand the influence of the flipped classroom on student attitude.

Nonetheless, differing implementations of the flipped classroom as mentioned in Section 1.1, alongside a range of contrasting findings in the literature concerning student affective responses, lead to questions relating to the true efficacy and impact of a flipped approach. This doctoral study attempted to better understand the impact of a flipped classroom through a secondary classroom setting in the topic of linear equations.

1.4 Teacher Considerations: Flipped Classroom Implementation and Technological Pedagogical Content Knowledge

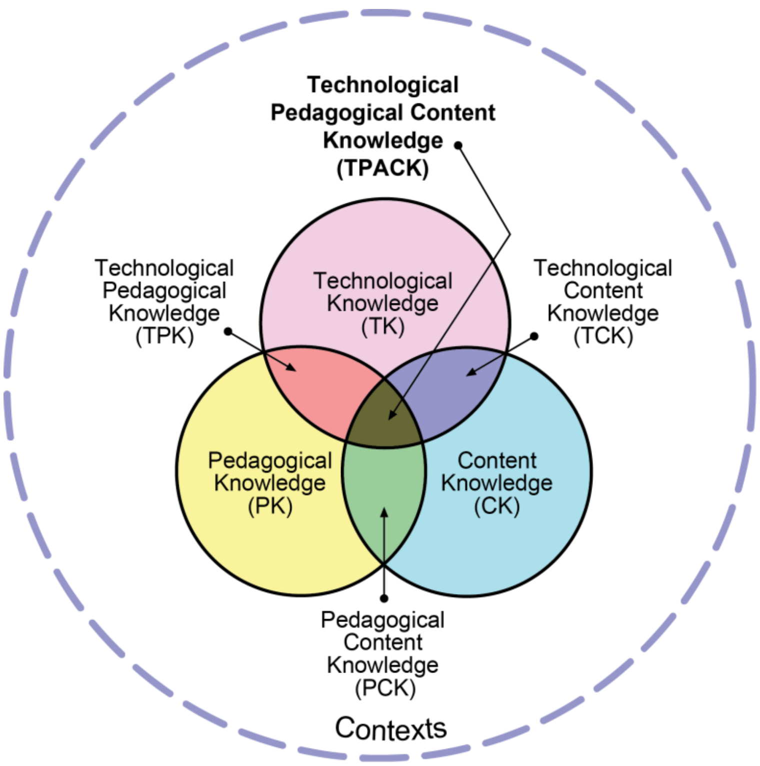
The teacher is central to imparting a change in pedagogy in the classroom. This section considers the implications involved from the individual teacher's perspective when a flipped classroom is not a familiar pedagogical practice. A brief overview of the challenges for teachers that have arisen through flipped classroom research is presented, positioning it within the established TPACK framework, which relate to the complexities brought about by teaching with technology.

The literature shows that flipped classroom implementation has presented challenges for teachers, primarily centring on shifts in teacher workload contributing to the need for upskilling with technology and additional time requirements (e.g., Akçayır & Akçayır, 2018; Lo et al., 2017). Furthermore, some researchers have reported 70+ working hours to redesign courses under a flipped approach, with some of this time solely dedicated to learning how to use the technology required to flip (e.g., Adams & Dove, 2016). However, relevant to the discussion of teacher implications and perspectives is that while increased teacher demands have been cited as a negative of the flipped classroom, there have also been reports of increased job satisfaction (e.g., Brunsell & Horejsi, 2013).

The literature demonstrates a higher demand placed on teachers in implementing a flipped approach. This is primarily due to the logic that successful implementation calls for the assimilation of teacher content knowledge of subject matter with awareness of alternative teaching strategies (pedagogy) and effective ICT (information and communications technology) use. With these inherent demands, the success in implementing a flipped classroom can vary widely depending on teacher competence in each of these areas. The overlap of and reliance on these separate areas (or constructs) have been described and conceptualised by the TPACK framework (Mishra & Koehler, 2006). While not exclusive to the flipped classroom, the TPACK framework builds upon Shulman's (1986) "forms of knowledge" construct to encompass the complexities brought about by teaching with technology. These frameworks and associated constructs are explored in-depth in the literature (e.g., Graham, 2011; Graziano et al., 2017; Koehler et al., 2013), and these perspectives helped to situate the definition of TPACK in this doctoral study. Content knowledge (CK) refers to a teacher's knowledge about the subject being taught, inclusive of all facts and theories underpinning the subject matter. In this doctoral research, CK relates to the teacher's understanding of the different types of linear equations and their knowledge of solving them. Pedagogical knowledge (PK) is a general form of knowledge relating broadly to how students learn, curriculum planning, and classroom management. In this doctoral research, PK relates to the teacher's sequencing and scaffolding of lessons to foster student understanding of linear equations. Pedagogical content knowledge (PCK) refers to the teacher's knowledge about the practices or methods involved in delivery of teaching for learning subject content; it covers awareness of misconceptions that are likely pre-existing or developed, as well as an understanding of pedagogical approaches that are most conducive to effective teaching and learning. In this doctoral research, PCK relates to the teacher's understanding of arithmetical and non-arithmetical equations and the need to convey appropriate and timely examples to ensure students are able to develop the understanding required to solve non-arithmetical equations. Koehler and Mishra (2009) argued that technology knowledge (TK) is in a constant state of "flux", more so than PK or CK due to the ever-evolving technological landscape of the 21st century. TK involves a dimension of technology content (TC) knowledge, which is an understanding of how the subject matter can be taught using technology. The assimilation of TK and TC throughout the aforementioned constructs gives rise to "technological pedagogical knowledge" or TPK. TPK is the understanding of how teaching and learning can change with the use of particular technologies. The intersect of TPK with mathematics was a large facet of this doctoral research when considering teacher experience, as flipped classroom implementation requires a teacher to utilise technology to convey aspects of the curriculum that may have previously had no reliance on TC or TK. These relationships are depicted in Figure 1.2.

Figure 1.2

Technological Pedagogical Content Knowledge (TPACK)



Note. From "Technological Pedagogical Content Knowledge" by M. J. Koehler, 2020 (http://tpack.org). Copyright 2012 by tpack.org. Reprinted with permission.

Given technology was a crucial component of the flipped classroom in this doctoral research, effective implementation required a teacher who could maintain all constructs within the TPACK framework. Ultimately, this would result in a teacher being responsible for not only creating lesson material (PK and CK elements) but also ensuring that this was appropriately managed with the new technological aspects, such as creating video-based tutorials and posting these online (i.e., TK and TC elements). The selection of the technology used to convey lesson content would need to (at least) parallel what could have been achieved through their regular (nonflipped) classroom, without sacrificing copious amounts of additional time that would render it an inefficient practice on the teacher's behalf.

Given the demands incumbent on modifying the mode of pedagogical approach to incorporate technology (i.e., the flipped classroom), and that issues with teachers being able to manage technology are reported in the flipped literature (e.g., Akçayır & Akçayır, 2018; Johnson & Renner, 2012; Speller, 2015), there is a need to further understand the teacher experience when attempting to implement a flipped approach. The teacher's experiences and perspectives were therefore gathered through this doctoral research to help gauge the ongoing practicality of implementing a flipped approach in a secondary classroom.

1.5 Research Problem

Given the increased access to technology in secondary school classrooms (e.g., DEAG, 2013; DEEWR, 2013), new pedagogical approaches to mathematics have become available in secondary schools. The impact and efficacy of a technology-enabled flipped classroom and student understanding and attitude in secondary mathematics have not yet been fully explored (see Chapter 2 for an overview of the literature). The lack of consistency in pre- and in-class activities in the flipped classroom literature has complicated the ability to draw direct comparisons among existing studies of the flipped classroom. Furthermore, while literature relating to the efficacy of a flipped approach is continually emerging, the focus has largely remained on postgraduate and non-Australian settings (refer to Chapter 2). The differences in culture, attitudes, and motivational factors that could exist between overseas postgraduate settings and Australian secondary environments should not be overlooked in their capacity to play a role in the success of a flipped approach.

This research aimed to compare the impacts of two teaching approaches (flipped vs. a teacher's regular approach) in the topic of linear equations. The research compared two separate Year 9 mathematics classes, taught by the same teacher, in an Australian co-educational secondary school. Student understanding of concepts and skills required for solving linear equations was compared for an experimental (flipped) and control (nonflipped) group. This research also compared students' attitudes towards mathematics between each group. The teacher's experiences and perspectives when implementing a flipped approach were also investigated. Through the data generated from a case study of each class, this research aimed to provide insight into the efficacy of a flipped classroom pedagogy in an Australian secondary mathematics classroom context.

1.6 Research Questions

Through making comparisons between a flipped (experimental) and regular instruction (control) group, this research set out to address the following research questions (RQs):

RQ1. What understanding do students in a flipped and regular group demonstrate when solving linear equations?

a. What understanding is demonstrated in each group before the linear equations topic?

b. What understanding is demonstrated in each group directly after the linear equations topic?

c. What similarities or differences in understanding exist between each group before and directly after the topic?

RQ2. What similarities or differences in understanding exist between each group directly after the topic and after 3 weeks?

RQ3. Does a flipped approach influence students' self-reported attitude to mathematics any differently to a regular approach?

a. What are the student attitudes to mathematics for the flipped and regular groups before the linear equations topic?

b. What are the student attitudes to mathematics for the flipped and regular groups after the linear equations topic?

c. What similarities or differences exist between each group before and directly after the topic?

RQ4. What are the student experiences and perspectives of the flipped classroom after utilising this approach to learn linear equations?

RQ5. What are the teacher experiences and perspectives of implementing a flipped learning approach for the first time?

a. What requirements exist for a teacher to implement a flipped classroom?

b. What are the key perceived outcomes in implementing a flipped classroom when teaching students to solve linear equations?

c. What recommendations can be given to teachers in the transition to a flipped classroom?

1.7 Overview of Thesis Structure

Through the ensuing chapters of this thesis, the impact of a flipped classroom approach in a secondary school classroom is explored and compared to the same teacher's regular (nonflipped) instructional approach. A detailed discussion and analysis of the literature concerning solving linear equations and students' attitudes to mathematics are presented through Chapter 2 to support the introductory concepts and background information provided in this chapter. Consideration is then given to the two predominant modes of teaching that can be incorporated as part of a flipped classroom (i.e., direct instruction and discovery-based teaching) before discussion about the documented impact on student achievement and attitude. Chapter 3 is the methodology chapter, which outlines the research design and data collection instruments, alongside defining the quantitative and qualitative components of this research. The quantitative student attitude data and the student results for linear equations understanding are presented through Chapter 4. The teacher's and students' experiences in the flipped classroom are explored through qualitative thematic analysis in Chapter 5. A detailed discussion and analysis of the data presented through Chapters 4 and 5 are then provided through Chapter 6, including a comparative discussion of the two pedagogical approaches in this research and reported outcomes of the flipped classroom in the literature. The final chapter presents conclusions and implications based on the knowledge generated through this research and suggests recommendations for schools to consider in their teaching and learning programs, alongside potential areas for future research.

Chapter 2.

Literature Review

This literature review discusses student algebraic understanding relating to the process of solving specific types of linear equations, including the common misconceptions exhibited by students and the subsequent implications for teachers. The research on student understanding then extends from the importance of algebraic understanding when solving equations to the importance of attitude towards learning mathematics. The ambiguity in the construct of attitude in mathematics education is presented, before providing a specific definition of attitude in this study. The overlap of technology in mathematics and student attitude is explored through the literature, alongside the constructs of confidence and engagement, which are the aspects of attitude studied in this doctoral research. The relevant literature concerning the flipped classroom is then explored and discussed concerning student outcomes—namely, student achievement, understanding, and attitude. Following the student-focused discussion, the literature relating to teacher perspectives on implementing a flipped classroom is explored. Finally, a summary of the current literature's limitations concerning the flipped classroom is presented to position the relevance and potential contributions of the present doctoral study in understanding the impact of a flipped approach in a secondary school classroom.

2.1 Solving Linear Equations

This section presents the literature relating to student algebraic understanding for solving linear equations. The concept of "arithmetical" and "non-arithmetical" equations is introduced to begin to make distinctions between different stages of algebraic understanding and the reasoning behind such differences. Issues concerning student understanding and the role of the pedagogical approach in developing student understanding of solving linear equations are further highlighted through this section.

2.1.1 Two Types of Equations: Arithmetical and Non-arithmetical

Kieran's (1981) review of research involving elementary- and high school-aged students highlighted that "an equivalence interpretation of the equal sign is one that does not seem to come easily or quickly for many students" (p. 317). This is built on the premise that students would often interpret the equals sign as an operation, rather than as representing the notion of equality between the two sides. Filloy and Rojano's (1984) clinical study, which involved interviews with 14 students undertaking secondary school algebra, reinforced the issues of equivalence concluded by Kieran (1981), exemplifying the difficulty that students experienced when their thought processes were grounded in arithmetical methods. Through qualitatively drawing on their earlier (1984) clinical study, Filloy and Rojano (1989) hypothesised an evolutionary line to exist when moving from an "arithmetical language" to an "algebraic language". They postulated each evolutionary phase to be a representation of a learner's progress when dealing with algebraic concepts, which could be visualised as "cut-points separating one kind of thought from the other" (p. 19). They shared two examples to illustrate the two types of equations they considered separated by these cut-points.

The first type of equation is the arithmetical equation, which involves what Filloy and Rojano (1989) termed "an arithmetical notion of equality" (p. 19). An example of an arithmetical equation would take the form: $Ax + B = C$. In these equations, one side of the equation corresponds to operations that can be performed on numbers (known or unknown), and the other side is the result of having performed such operations. In algebra, these types of equations can be solved by considering C and then "undoing" the operations on the left hand side of the equation with reference to C. This process of undoing has been described interchangeably as "working backwards" (e.g., Kieran, 1992). In the example of $Ax + B = C$, B can be subtracted from both sides and each side divided by A to obtain the solution for x. The key idea here is that the unknown part of the equation (the variable x) appears only on one side of the equals sign. Therefore, the arithmetical understanding of "undoing" on one side of the equals sign allows the other side of the equals sign to be the result of those calculations and thus the solution to the equation.

By contrast, an arithmetical notion of equality does not suffice for non-arithmetical equations. Instead, solving these equations requires "operations drawn from outside the domain of arithmetic", or more specifically, they involve "operations on the unknown" (Filloy & Rojano, 1989, p. 19). The arithmetical notion that is applied to the equation in the first example will not produce solutions for non-arithmetical equations. An example of this type of equation takes the form: Ax + B = Cx + D. For a learner to make sense of such an equation, they must first understand that the expressions on either side of the equals sign are equivalent and then use the appropriate actions to solve. The critical difference is that now students have "unknowns" on both sides and are reliant on understanding the equals sign representing equivalence between the two expressions, as opposed to arithmetical calculations to be performed. Filloy and Rojano (1989) contended that to solve these equations, profound changes need to occur in the learner's arithmetical habits or thought processes, including an understanding of equality when unknowns are involved. The contention that changes to thought processes relating to equivalence do not come spontaneously was emphasised by Kieran (1981) and continues to be prevalent in more recent literature (e.g., Simsek et al., 2019; Welder, 2012).

Filloy and Rojano (1989) highlighted a need for changes in students' conceptual thinking to be addressed through appropriate instruction. Ongoing research related to solving linear equations continues to outline and discuss the differences in complexity that arise through solving different types of linear equations and the need for suitable teaching interventions to address these (e.g., Herscovics & Linchevski, 1994; Kieran, 1992, 2004, 2013; Linsell, 2009; Sfard & Linchevski, 1994). The findings of their research, along with the implications for mathematics education, are discussed further in the ensuing sections.

2.1.2 Solving Linear Equations: Student Understanding and Methods for Solving

While the work of Filloy and Rojano (1989) helps to conceptualise the differences in the types of linear equations, others have further built on this conceptualisation, albeit with different terminologies. Sfard and Linchevski (1994) proposed the notion of a didactic cut, which is the demarcation line between the "operational" and "structural" aspects of algebra.

Through interviews involving 14 students (Grades 7 to 10), they demonstrated that the introduction of non-arithmetical equations brought about a heightened level of difficulty that could not be overcome through previous forms of intuition and standard arithmetic strategies (i.e., the processes required to solve these equations did not arise spontaneously for students). The ability to work through these types of equations required a specific understanding of the role of the objects (i.e., algebraic terms/unknowns) and the symbols in an equation (i.e., an equals sign indicating equivalence). Therefore, the need for additional strategies to be taught explicitly for students to develop their algebraic and relational understanding becomes further apparent, and the need for this development is further emphasised through the literature. Stacey and MacGregor (2000) provided an example of this in their study involving 900 students from 12 Australian schools. Through collecting written samples of work and conducting 30 one-to-one interviews with students aged 13 to 16 (these students were estimated to have had 3 to 4 years' previous algebra experience), they found that students "deflected" from an algebraic path at every stage of the process of solving algebraic problems. Instead of applying non-arithmetical or algebraic strategies, they observed that students tended to rely on other thinking that was grounded in arithmetical processes. The reliance on arithmetical strategies in favour of the required algebraic strategies is a theme that has prevailed since these earlier studies. Gasco and Villarroel (2012) emphasised this through the persistence of 215 secondary school students to continue with arithmetical processes when attempting to solve linear equations, rather than utilising the required algebraic technique. They postulated this to be due to an arithmetical way of thinking being easier for students to comprehend, which is similar to the conclusions of Stacey and MacGregor (2000) who found that students tended to fall back on what they had prior experience with and thus used what they were better "grounded in".

In addressing the issues presented to both students and teachers when dealing with linear equations, Kieran (1992) outlined seven discernible methods that a student could use when solving linear equations:

(a) use of numbers facts,

(b) use of counting techniques,

(c) cover-up,

(d) undoing (or working backwards),

(e) trial-and-error substitution,

(f) transposing (that is, Change Side-Change Sign),

(g) performing the same operation on both sides. (p. 400)

From the abovementioned list, the first five listed methods can be applied using an arithmetical notion of equality, as described earlier. The latter two points (transposing and performing the same operation on both sides) are deemed the more formal methods of solving. These formal methods of solving highlight the evolutionary phases for students proposed by Filloy and Rojano (1989). The final two are the types of methods that will not come spontaneously from students' prior knowledge of arithmetic but instead would require an algebraic approach—that is, a change to their arithmetical habits and conceptual understanding (e.g., Filloy & Rojano, 1989; Sfard & Linchevski, 1994; Stacey & MacGregor, 2000). Herscovics and Linchevski's (1994) research supports the notion that such algebraic thinking does not come spontaneously and described the movement from calculating with numbers to operating with the unknown as a "cognitive gap" between arithmetic and algebra for students. The work of Linsell (2009) provides further evidence for the concept of a cognitive gap. Through diagnostic interviews of 621 Years 7 to 10 students, Linsell described a "hierarchy of solving strategies" available to students when attempting to solve linear equations. He asked students to solve a series of increasingly complex equations and to provide an explanation of their thinking while solving. Through this, Linsell noted a propensity for students to revert to guess-and-check methods when attempting to solve more difficult questions. In further analysing the patterns of solutions to particular questions involving linear equations, Linsell established a hierarchy of solving strategies in which he noted that equations solved by transformation techniques were used "by the most able students and guess and check by the least able" (p. 336). Linsell (2010) again emphasised the sophistication required by students to execute the latter two methods of Kieran's (1992) list (i.e., transposing and performing the same operations on both sides) in his examination of the written work of 1,007 Years 9 to 11 students, which revealed similar patterns in algebraic understanding as evidenced in his 2009 study. In particular, he noted a small proportion of students were able to solve using transposing strategies (i.e., points F and G on Kieran's [1992] discernible methods list), and a proportion of struggling students were restricted to more "primitive" strategies of guess and check (i.e., trial-and-error substitution) and use of number facts (i.e., points A and E on Kieran's [1992] list).

The abovementioned studies highlight that a student's ability to solve linear equations is underpinned by their knowledge and use of a range of solving methods, alongside their algebraic (non-arithmetical) understanding. Essential to consider is that while some algebraic equations can be solved utilising Kieran's (1992) first five "less sophisticated" methods, the successful use of such techniques may not necessarily indicate students' algebraic understanding as they could be largely grounded in arithmetical thought. The challenge with discerning a student's level of algebraic understanding comes, then, from ensuring appropriate equations that not only test the student's ability to solve an algebraic equation but also highlight the student's understanding in doing so. A point of departure is required in the style of questions asked: While "easier" style questions may be solved through arithmetical thinking, more difficult questions should be given such that they are only (as best as possible) solved through non-arithmetical methods or formal algebraic strategies (transposing/performing the same operations to both sides) to demonstrate student recognition of equivalence between expressions and appropriate algebraic understanding.

2.1.3 Solving Linear Equations: Importance of Pedagogical Approach

Established through the above sections is that students can solve different types of linear equations through a variety of methods. Furthermore, the method and degree of success to which students can solve such equations are indicative of algebraic understanding. However, notable from the above discussion is the notion that the ability to solve non-arithmetical equations does not come spontaneously for students. Therefore, a teacher's pedagogical approach should provide suitable opportunities for this understanding to be developed.

Stacey and MacGregor (2000) highlighted the teacher's role in providing suitable opportunities for students to learn appropriate mathematical methods to solve algebraic equations. Through the examination of written work and interviews, their study revealed students' tendency to revert to thinking grounded in arithmetical problem-solving methods (see Section 2.1.2). This method of problem-solving, which is approached through intuitive, non-algebraic methods, soon forms a restriction on the types of algebraic equations students can solve and, if left uncorrected, forms a significant factor in students developing misconceptions or inability to solve algebraic equations.

However, the literature continues to highlight the importance of pedagogical approaches by emphasising the teacher's role in recognising the underlying reasons for students making errors in their thinking. Huntley et al.'s (2007) investigation into the approaches of third-year high school mathematics students when solving non-arithmetical equations provides an example of this. Through interviewing and reviewing the work of 44 pairs of third-year high school mathematics students in the United States, they identified the types of strategies students use when solving types of linear equations; these findings support the conceptual issues discussed in this thesis (Sections 2.1 and 2.2) and the underlying notion that many students struggle with solving nonroutine/non-arithmetical linear equations. The importance of the teacher's approach in supporting a student's transition to solving nonroutine linear equations is reiterated through their conclusion, which recommended teachers explicitly teach appropriately sequenced, nonroutine problems to students to better support their learning how to solve linear equations.

The importance of teaching approach is further highlighted by Linsell (2009) who discussed the importance of teachers realising that success in solving linear equations in one context may not necessarily translate to another, and this is primarily due to the algebraic methods required of the question (i.e., arithmetical, one step vs. non-arithmetical, two-step equations). Sufficient insight and understanding by the teacher (i.e., CK and PCK from TPACK) are required to scaffold a student's understanding effectively. The importance of the teacher's approach is revisited through the work of Akhtar and Steinle (2013) who highlighted that while teachers were aware some students did not have a relational definition of the equals sign, they often overestimated their students' ability to overcome any difficulties associated with it. The importance of a teaching approach that caters to building student understanding is a critical point to hone, as explicit teaching of strategies is required to ensure students are capable of solving linear equations, while at the same time, an appropriate selection of equations or questions need to be posed to ensure the student can demonstrate a repertoire of strategies. The selection of questions coupled with the approach to teaching are decisions made during a teacher's planning, and these can play a crucial role in the development (and identification) of student understanding.

Despite differing terminologies (i.e., the cognitive gap or cut-points), the literature consistently demonstrates a need for students to transition from arithmetical to non-arithmetical thinking to have the necessary algebraic understanding to solve linear equations. While success in solving linear equations may start with an intuitive knowledge of standard numerical arithmetic equations, the studies mentioned above make clear that teacher intervention is needed to assist students in the development of nonspontaneous algebraic understanding or thinking. This development of algebraic thinking will then ultimately lead to students' capacity to solve complex linear equations (i.e., non-arithmetical equations).

2.2 Construct of Attitude in Mathematics Education

The previous section emphasised the importance of the appropriate application of algebraic methods; however, there are also attitudinal issues that are important to consider for student learning in mathematics. The mathematics education literature demonstrates a substantial history of research supporting the notion that positive attitudes, beliefs, and motivations can be positively correlated with higher effort, achievement, and aspiration in mathematics (e.g., Ma and Kishor, 1997; McLeod, 1992; Watt, 2006; Wigfield & Eccles, 2000). A subset of mathematics education research has further explored students' affective responses in mathematics, through focusing attention on the construct or definition of "attitude", highlighting the importance of student attitude to learning mathematics (e.g., DeBellis & Goldin, 1997; Di Martino & Zan, 2015; McLeod, 1992).

Ma and Kishor's (1997) meta-analysis highlights the significance of the link between attitude and mathematics, which includes 113 survey studies that span 27 years of research involving 82,941 students from 12 grade levels throughout the world. Their research revealed a positive relationship between student attitude towards mathematics and mathematics achievement, with student attitude identified as the causal influence in this relationship. Interestingly, while the combined effect size for all 12 grades was relatively weak (effect size of 0.12), a much stronger effect size was noted for students in the secondary years (effect size as large as 0.25) when compared to elementary years (effect size as small as 0.03). Large differences in effect sizes between these groups of students may suggest that student attitude could play more of a role in student achievement for secondary school-aged students, who were the focus of this present doctoral research. This positive correlation has been supported more recently through the research of Bhowmik and Roy (2016) who conducted a study involving 394 secondary school-aged students examining the relationship between attitude towards mathematics and subsequent achievement in mathematics. The researchers noted a significant positive correlation between students' attitudes towards and achievement in mathematics, leading them to conclude that it is likely for students' increased attitudes to translate to increased results.

While research has established links between attitude and achievement in mathematics, it is important to note that student attitude in mathematics has been defined and subsequently measured in many different ways in the literature. These differing definitions, measurements, and interpretations of attitude contributed to early criticism and confusion around the construct of attitude (Aiken, 1970; Kulm, 1980; Hart, 1989). The same criticisms of construct have continued in the literature and were more generally summarised by Zan et al. (2006) in their observations that

> researchers rarely gave explicit definitions of their construct, often leaving the definition to be inferred from the type of instrument used. This lack of conceptual clarity was related to the borrowing of instruments and constructs from psychology, without specific theoretical elaboration for mathematics education. (p. 115)

The clarity around the construct of attitude has continued to remain elusive, with the use of the term in more recent times being described as "vague" and "ambiguous" (see Di Martino & Zan, 2015 for a comprehensive review of such criticisms). However, Kiwanuka et al. (2017) attributed the multiple definitions and ambiguous nature of attitude towards mathematics to the multidimensional nature of the construct, with multiple factors—that is, confidence, engagement, enjoyment, emotion, behavioural response, belief—encompassed under the umbrella of attitude, thus reinforcing the need to be specific about what a researcher means when reporting attitude. While the multidimensional nature of attitude can perhaps be seen to contribute to the variety of definitions in the literature, Di Martino and Zan's (2010) view is that the multiple definitions available should be seen as enriching rather than limiting. This view is based largely on the definition presented by Daskalogianni and Simpson (2000) who considered attitude to have a "working definition" concerned more about suitability to context rather than a fixation on being correct. Consequently, it remains an important consideration for all research to define and specify exactly what is meant by attitude to assist readers in the interpretation of results and to not contribute further to the ambiguity of terminology.

The terminology of student attitude in this study refers explicitly to students' affective responses when learning mathematics, inclusive of enjoyment, confidence, and engagement.

2.2.1 Affective Domain and Student Attitude Within Mathematics Education

McLeod (1992) made a significant contribution to helping conceptualise the affective domain in mathematics education through categorising three constructs used throughout the literature: beliefs, attitudes, and emotions. McLeod provides examples to clarify these constructs, and these are presented in Table 2.1.

Table 2.1

An Overview of McLeod's Categorisations of the Affective Domain

Category/Construct	Examples
Beliefs about mathematics about self about mathematics teaching about the social context	Mathematics is based on rules I am able to solve problems Teaching is telling Learning is competitive
Attitudes	Dislike of geometric proof Enjoyment of problem-solving Preference for discovery learning
Emotions	Joy (or frustration) in solving nonroutine problems Aesthetic responses to mathematics

Note. From "Research on Affect in Mathematics Education: A Reconceptualization" by D. B. McLeod, in D. A. Grouws (Ed.), *Handbook of Research on Mathematics Teaching and Learning: A Project of the National Council of Teachers of Mathematics* (p. 578), 1992. Macmillan Publishing.

McLeod (1992) described these constructs as differing in their stability, intensity, and the degree to which cognition plays a role. This conceptualisation of the affective domain provides a clear distinction between different affective constructs and a clear separation from the cognitive aspects of mathematics education. The significance of McLeod's work is emphasised through Zan et al.'s (2006) synthesis of attitude literature, highlighting McLeod's work to be the centrepiece of affect in mathematics education. McLeod's conceptualisation of the affective domain has continued to be embedded in definitions and has been built upon further over the years (e.g., Barkatsas et al., 2009, DeBellis & Goldin, 1997; Di Martino & Zan, 2015). However, Zan et al. (2006) conceded McLeod's work does not amount to a full theorisation of the area and instead contended that ongoing work is required to better understand the interaction between cognition, metacognition, and affect. In turn, they indicated two broader directions of research on affect in mathematics education, one aiming to critique and revise McLeod's basic concepts and the other to break new ground. These are an effort to construct better-founded theoretical frameworks and a broader range of methodological instruments.

Research following McLeod's conceptualisation in mathematics research has included terms such as confidence, engagement, and motivation to describe student attitude (e.g., Barkatsas et al., 2009; Pierce et al., 2007). This doctoral research utilised McLeod's (1992) conceptualisation, coupled with the interaction between technology and the affective domain, as integrated in the work of Pierce et al. (2007) and discussed further in Section 2.2.2.

2.2.2 Attitude With Technology and Mathematics

Given an increasing prevalence of technology in education, Pierce et al. (2007) hypothesised a model to better understand the role of technology in influencing student affective response in mathematics. Their study focused on the measurement of student attitude in response to technological teaching interventions, building on McLeod's (1992) categorisations as a guiding framework. Important to note in their measure of attitude is that they made no distinction between the constructs of "belief" and "attitude", and that they used "attitude" and "affective" interchangeably to encompass both feelings and opinions about doing and learning mathematics. This explicit interpretation of the term attitude removes ambiguity from any interpretation and aligns with what Daskalogianni and Simpson (2000) termed a working definition. Pierce et al.'s (2007) working terminology for attitude, which included both belief and affect, is the same working definition used in this doctoral research study given the substantial overlap between the scale developed by Pierce et al. (2007) and the intentions of this doctoral research.

Barkatsas et al. (2009) has previously argued the case that "engagement, confidence in mathematics, confidence with technology, and achievement are interrelated" (p. 563), particularly for students in secondary school mathematics. Given the similar structure in intervention between the Pierce et al. (2007) study and this doctoral research (i.e., increased use of technology), it was both appropriate and practical to share the same interpretation of attitude. This working definition of attitude involves the assimilation of the "beliefs" and "attitudes" category (Table 2.1) as outlined by McLeod (1992) and encompasses two primary constructs: confidence and engagement. These constructs are detailed below in terms of their relation to this doctoral research and their relevance to previous work in the affective domain.

2.2.2.1 Construct of Confidence in Mathematics

McLeod (1992) discussed confidence as one of the "mini-theories" related to the affective domain, conjecturing that it would be reasonable to consider it a belief about one's competence and therefore a subset of the belief construct outlined in Table 2.1. However, others have defined student confidence in mathematics to be a subset of student attitude (e.g., Dunham, 1990; Galbraith & Haines, 1998; Pierce et al., 2007). Importantly, McLeod (1992) conceded that it is often "difficult to separate the research on attitudes from the research on beliefs" (p. 582); therefore, the classification of confidence as an attitude construct should not be considered an unusual categorisation.

This doctoral research focused on "confidence in mathematics" and, through Pierce et al.'s (2007) established definition, it is defined as "a student's perception of their ability to attain good results and their assurance that they can handle difficulties in mathematics" (p. 290). This definition was selected in preference to others as it fit well with the present doctoral research objectives—namely, it separates the notion of confidence from other affective domains such as those that may arise from enjoyment, providing a more specific categorisation of a student's confidence in dealing with mathematics without being confounded by other factors of attitude (e.g., interest feelings about mathematics in general). Additionally, as Pierce et al. (2007) explored this construct in a secondary school context, an obvious advantage of building on previous research becomes available without having to unnecessarily reposition the scope of what is defined and measured as mathematics confidence.

2.2.2.2 Construct of Engagement in Mathematics

According to Fredricks et al.'s (2004) review of school-based engagement, the construct of engagement is multifaceted, with three main aspects: behavioural, emotional, and cognitive. Fredricks et al. (2004) contended that while these three different types of engagement appear in the literature, there tends to be significant overlap between them. The existence of overlapping elements makes it essential that the construct measured is appropriately and explicitly defined to avoid confusion and ambiguity about what is being referred to (and measured) when discussing "engagement".

Emotional engagement encompasses positive and negative reactions to teachers, classmates, and school and is presumed to influence willingness to do work (Fredricks et al., 2004). There is a substantial overlap between this definition and that of McLeod's (1992) definition of emotion and attitude in the affective domain (see Table 2.1), with positive and negative feelings towards mathematics being indicators of a student's affective disposition in mathematics and, therefore, their emotional engagement.

Cognitive engagement references an individual's willingness to apply the necessary effort for the comprehension of complex ideas and mastery of skills (Fredricks et al., 2004) and is often referred to as "motivation" in other theoretical frameworks (i.e., the EVT; see Wigfield & Eccles, 2000). Emotional engagement has a substantial overlap with cognitive engagement when the focus on a student's feelings or dispositions concerns a specific subject. Pierce et al. (2007) discussed the overlap and combination of these two areas as an overall measure of "affective engagement", which draws together the emotional aspects of engagement within the cognitive field of mathematics subject material.

Behavioural engagement relates to student participation and involvement with academic, social, or extracurricular activities, which are considered the foundation steps crucial for achieving positive academic outcomes (Fredricks et al., 2004). This definition, which is primarily concerned with "participation", is consistent with Pierce et al. (2007), who attributed student participation in mathematics classes as a measure of behavioural engagement.

The malleable nature of engagement makes it an interesting construct to observe in response to changes in pedagogical approach. Large-scale studies have demonstrated a positive correlation between student engagement and achievement (e.g., Marks, 2000). Furthermore, changes to classroom structure have been implicated to play a substantial role in influencing students' behavioural and emotional engagement (Barkatsas et al., 2009; Fredricks et al., 2004). Given the change in pedagogy brought about through the introduction of a flipped classroom, it would be reasonable to conjecture that student engagement has the potential to be impacted. Monitoring student engagement before and after a flipped classroom intervention was considered a useful measure as part of determining student attitude to better understand the impact of the flipped classroom in a secondary mathematics environment.

2.3 Flipped Classroom: Overview and History

This section highlights the growing body of research indicating increased popularity of the flipped classroom as a pedagogical approach. The origins of the flipped classroom in the literature are discussed, alongside the differing terminologies used (i.e., inverted and flipped). Finally, a summary of differences between pre-class and in-class activities in flipped classroom research (introduced in Section 1.1) are detailed to highlight the implications of comparing the current literature.

Over the last decade, the flipped classroom has become a talking point in educational circles among both researchers and practitioners (e.g., Fulton, 2012; Johnson & Renner, 2012; Szparagowski, 2014; Tucker, 2012). The growth in the number of members in the Flipped Learning Network (FLN, n.d.), a community devised to support educators in their flipped learning endeavours, evidenced the growing popularity of the concept, with member numbers increasing from 2,500 in 2012 to 20,000 by 2014 (Yarbro et al., 2014).

Less than a decade prior to this doctoral research, authors signalled caution in interpreting the literature due to the limited available studies (Bishop & Verleger, 2013; Kadry & Hami, 2014; Love et al., 2014, 2015). However, research into the efficacy of the flipped classroom has intensified over recent years, and the number of peer-reviewed articles has been increasing to the point where meta-analyses (e.g., Lo et al., 2017) and large-scale systematic reviews (e.g., Akçayır & Akçayır, 2018) have been published. However, the discussion and literature surrounding flipped research do not identify one sole person or group as the creators of the concept. There are several prominent contributors, some credited with the vision and others for the recent popularisation of the concept, and these are discussed below.

Flipped classroom literature has origins at the turn of the century, with Baker (2000) seeking alternatives to move lecture-based material out of the classroom using technology (Baker, 2000, 2011; Kadry & Hami, 2014). Baker's (2000) ambition was to become free of the "tyranny of the lecturer" (p. 13) and instead free up in-class time for more active student participation with the content. These notions gave rise to what Baker termed the "classroom flip". Lage et al. (2000) published their experiences in transferring undergraduate economics lectures into a variety of different formats, including videorecorded lectures and audio-embedded PowerPoint slides. Students were expected to access and view this material before class and were then encouraged to ask content clarification questions of their instructor in class. Once the instructor had covered clarifying questions, the class time was used to conduct economic experiments corresponding to the topic covered, which allowed students to view economics principles in action. Lage et al. referred to this mode of teaching as "the inverted classroom", meaning, "events that have traditionally taken place inside the classroom now take place outside the classroom, and vice-versa" (p. 32). The more recent popularisation of the flipped classroom is generally credited to the work of Bergmann and Sams (2009, 2016) who used videorecordings and annotations to transfer their regular chemistry lectures to an online format in a process they described as the flipped classroom.

While the flipped classroom concept remains the same between the three studies, these examples highlight that the same general concept is often referred to by different yet interchangeable names (flipped or inverted). However, in all instances, the flipped classroom is a teaching model that reverses the usual timing (and location) of content delivery and homework; that is, the usual structure becomes "flipped" or "inverted". The instruction once given during class time is now given as homework through video lectures, reading tasks, audio–visual presentations, voice recordings, or any other delivery method conducive to delivering instruction. This transfer of teaching to outside the face-to-face classroom then allows for the practice problems, which would have otherwise occurred for homework, to be worked on in the classroom in the presence of the teacher. All aspects of instruction are essentially rethought to allow for maximisation of what Tucker (2012) described as the scarcest resource of all in teaching: time.

However, a flipped approach is slightly more nuanced than the above may suggest, as there is a wide range of ways that a flipped classroom can be implemented. These differences have contributed to differing opinions on the use and value of such an approach in educational settings (e.g., Halili & Zainuddin, 2015; Szparagowski, 2014; Jensen et al., 2015). A recent overview of the literature confirmed that there is currently no standard practice for a flipped classroom approach in mathematics (Lo et al., 2017), with no mandate on how content should be delivered when flipped—that is, no specific expectations for the at-home component (pre-class activities), nor any specific expectation on what should happen with the face-to-face class time (in-class activities). This particular facet has led authors (e.g., Jensen et al., 2015) attributing the positive results reported in flipped classroom research to be confounded by the product of in-class activities. It is therefore essential when trying to measure and compare the impact of the flipped classroom to be specific when referring to what pre-class and in-class activities are involved or changed through a classroom flip.

However, while there are reported inconsistencies in how a flipped classroom pedagogy can be implemented, there are some constants. Namely, the flipped classroom generally involves two components; a pre-class activity and an in-class activities. In the case of technology-enabled flipped classrooms, the pre-class activity could be viewing videos tutorials. The in-class activity is then generally the activity that would occur in a face-to-face format, which may include individual or group-based work (how this is achieved in class can vary, hence the inconsistent nature of flipped practices). It is, however, pertinent to understand that a flipped classroom is not merely a substitution of classroom instruction for take-home videos, but an understanding that the approach requires appropriate integration between the content that is covered outside the classroom and how class time is subsequently used, with these points echoed throughout the literature (e.g., Halili & Zainuddin, 2015; Lo et al., 2017; Sams & Bergmann, 2013; Tucker, 2012). Indeed, the most meaningful learning in a flipped classroom occurs through efficient use of "extra" class time made available through transferring the content or instruction to homework (Baker, 2000, 2011; Lage et al., 2000; Tucker, 2012) and the subsequent use of in-class time (Jensen et al., 2015). It is important that both pre-class and in-class activities be well thought out to maximise a flipped approach (Bergmann and Sams, 2016). Difficulty can arise, therefore, when interpreting research that does not report on aspects of pre- and in-class activities; given there is no standard flipped approach, understanding the true impact of such an approach becomes problematic in the absence of transparency in the pre- and in-class activities.

2.4 Two Pedagogical Approaches Utilised in a Flipped Classroom

The flipped classroom can assist with two forms of pedagogical approaches: direct (explicit) and discovery-based (active/inquiry) learning. This section presents a broad overview of the two types of pedagogical approaches primarily utilised through a flipped classroom to provide a common understanding of the pedagogical terminologies used through this doctoral research. The explicit definition for each pedagogical approach becomes increasingly important when the benefits of a flipped classroom have been speculated to have no influence on student learning or attitude when discovery-, active- or inquiry-based (constructivist) pedagogical approaches are undertaken (see Jensen et al., 2015). An overview of the two pedagogical approaches—direct (or explicit) instruction and discovery-based (active/inquiry) learning—is presented below.

2.4.1 Direct (or Explicit) Instruction

The term direct instruction generally refers to that led by a teacher, who helps students build knowledge through the explicit teaching of concepts, rules, and strategies (Kozioff et al., 2000; Rosenshine, 1986, 2008). It is common for the term direct instruction to appear as synonymous and interchangeable with the term explicit instruction (Martin, 2015). Hattie (2008) commented that a common mistake among most interpretations of direct instruction is that it is often confused with a teacher "talking from the front". This particular mistake in interpretation has led to many students and teachers carrying the mantra "constructivism good, direct instruction bad" (Hattie, 2008, p. 204). While there is a wide range of differing interpretations of the term in pedagogical literature, Rosenshine (2008) deciphered the common instructional elements of the various reported facets of direct instruction to be "guided practice, active student participation and fading teacher-directed activities" (p. 5). These common instructional elements to direct instruction are grouped into four categories:

1. Reducing the difficulty of task during initial practice

   – Presenting new material in small sections

2. Providing scaffolds and support

– Modeling of the procedure by the teacher
– Thinking aloud by the teacher

3. Providing supportive feedback

– Providing systematic corrections and feedback
– Providing students with fix-up strategies
– Providing expert models of the completed task

4. Providing for extensive student independent practice. (Rosenshine 2008, pp. 4–5)

Rosenshine's (2008) instructional elements appear in line with others' views on direct instruction. For example, they focus on general procedures for knowledge acquisition (e.g., Stein et al., 1997) that later develop to allow for faded teacher involvement (e.g., Maccini & Gagnon, 2000). These direct instruction elements are traditionally delivered within the classroom, and Hattie's (2008) meta-analysis revealed the considerable effect size that direct instruction can have on student success when performed "correctly". Given that the flipped classroom can be used as a vehicle for delivering direct instruction, it would be reasonable to conjecture that a flipped classroom provides its own unique slant to delivering the four categories of direct instruction as presented above (i.e., pre class). The effectiveness of a flipped approach in delivering components of direct instruction outside the face-to-face classroom requires further investigation in a secondary mathematics context. More specifically, questions surrounding the effectiveness of a technology-enabled flipped approach to direct instruction when teaching secondary students to solve linear equations are yet to be fully addressed.

2.4.2 Discovery (or Inquiry) Based Learning

Through their review of the literature, Alfieri and colleagues (2011) contended that discovery-based learning occurs whenever a learner is not provided with the explicit information or conceptual understanding relating to a particular area. Instead, these learners are required to independently find and acquire the information and understanding relating to the area studied. This is in contrast to the aforementioned direct instructional approach, where the teacher scaffolds learners through the stages of knowledge acquisition. When referenced to direct instruction, the work of Hattie (2008) shows a more modest effect size for inquiry-based learning (or problem-based learning). However, as Liem and Martin (2013) discussed, modest results may be the result of inquiry teaching strategies being introduced too early in the learning sequence. Liem and Martin (2013) suggested that only after an appropriate level of direct instruction could a satisfactory level of discovery-based learning occur. This suggestion could indicate that inquiry-based learning may not be conducive to novice-level learners, as there needs to be an appropriate level of prerequisite knowledge before a learner can interact further through discovery- or inquiry-based means. When considering the "cognitive gap" in algebraic thinking (discussed in Section 2.1.2), it could be reasonable to conjecture that solving linear equations in an early secondary mathematics context is not initially compatible with an inquiry approach given the importance of explicit teacher instruction when dealing with non-arithmetical equations.

However, when considering Liem and Martin's (2013) view that effective discovery-based learning occurs when students are not entirely novice and have had sufficient instruction upon which to build, the efficacy of utilising a flipped approach becomes more apparent. The pre-class activity of a flipped approach may provide the opportunity for students to receive the necessary information to upgrade their novice understanding of the topic through initial direct instruction. Others have cited this as an advantage of the flipped classroom, with Bergmann and Sams's (2016) contention that a flipped classroom is the blending of direct instruction with constructivist (inquiry-/discovery-based) learning. This notion further establishes the potential position of a flipped approach in its ability to utilise (and/or enhance) either direct or discovery-based instruction. The next section explores the literature surrounding the flipped classroom and its effectiveness at delivering direct and/or inquiry-based learning.

2.5 Flipped Classroom: Student Understanding and Achievement

This section explores the impact of the flipped classroom when implemented in a range of educational settings and academic subjects. This impact is discussed largely with reference to student achievement given the predominant focus on achievement within the literature (i.e., improvement of exam or test scores) as opposed to understanding (i.e., ability to solve specific equation types as discussed in Section 2.1). Furthermore, given the limited studies in secondary school environments, this impact is first identified and then explored through a range of academic subjects and educational settings before focusing on the flipped classroom in mathematics education within secondary school environments.

It is pertinent to note from the outset that despite an expanding literature, the research investigating a flipped approach in secondary education remains scarce, with higher education studies dominating the field (Akçayır & Akçayır, 2018). Furthermore, while there is a heavy focus on student "achievement" (typically measured through raw course grades or exam results) in the flipped classroom, there is a dearth of literature focused on student understanding. This is an important consideration, as achievement and understanding can be measures of two separate aspects of mathematics, depending on how the assessment is constructed (i.e., where there is an appropriate balance of questions for solving varying levels of arithmetical and non-arithmetical linear equations). Achievement, as measured in the rawest sense, is often a measure of how many questions a student correctly responds to, without any specific delineation between the levels of difficulty of those questions. Understanding, however, provides opportunities to gain further insight into how well students have grasped concepts, which is particularly important when considering the levels of understanding available within linear equations (i.e., arithmetical and non-arithmetical equations). Section 2.1 of this literature review discussed the importance of student understanding in solving linear equations and the need for specific questions to gauge this understanding. Nonetheless, an ever-growing body of literature is beginning to provide a foundation from which to validate the contention that a flipped approach can influence student outcomes.

2.5.1 Flipped Classroom Improves Student Achievement

Bergman and Sams (2009) used video podcasting in chemistry classes to eliminate the need for in-class lecturing and asked students to watch as a pre-class activity. Subsequently, they noted an increase in the productivity of class time—effectively freeing up an additional 50% to 60%—that was used to assist students with their individual learning needs. Anecdotally (without reference to specific data), they noted students had a better grasp of the content in their classes. In a further attempt to gain a numerical perspective of student achievement, they compared the previous state exams (Colorado, United States) with their flipped cohort and previous years' nonflipped cohorts. They found that their students' average results were lower in the flipped group; however, they attributed this to the fact that in the same year they decided to flip, they had also lowered the mathematics prerequisite for enrolment in their course, speculating that this would have impacted the overall state exam. Separately, they compared the average scores of students on identical tests given before and after implementation of the flipped model, and this comparison revealed students performed the same. However, given these were lower performing students to start with (when compared with previous years), they concluded this may be evidence that the flipped approach was just as, if not more, effective than a "traditional" classroom.

Emerging from Bergmann and Sams's (2009) work is a host of research-based analyses by other researchers linking the flipped classroom to positive academic outcome. Ruddick (2012) used results from college students undertaking an introductory chemistry course, comparing the exam and course grades of students undertaking a flipped approach (which she termed "reverse instruction") with those in a traditional lecture-based setting. Through these comparisons, Ruddick (2012) observed a statistically significant higher achievement for students who had undertaken a flipped approach when compared to students who had undertaken a traditional lecture series. While this seems promising, pertinent to note concerning the study's design is that comparisons between the flipped approach and the traditional lecture approach were not always made with the same teacher. While the flipped instruction group was always taught by the same instructor (Instructor A), the traditional lecture series was taught by other faculty members and only sometimes by Instructor A. Interestingly, when Instructor A taught the traditional lecture series, it had a higher percentage of success than all the other lecture sessions, highlighting the impact of the instructor in general and reinforcing a need to control for potential confounding variables such as teachers or instructors when attempting to make comparisons between teaching approaches. Ruddick (2012) does suggest that Instructor A's lecture students could have outperformed the other lecture students due to Instructor A's lecture-based students also having access to the online videos used for the flipped content (therefore having access to additional support materials). This revelation introduces another confounding variable given that one of the nonflipped cohorts effectively had access to two modes of pedagogy (a threat to validity; diffusion of treatment). This threat to validity pervades other research, clouding the results that demonstrated positive impacts of the flipped classroom (Låg & Sæle, 2019). For example, the work of Deslauriers et al. (2011) highlights an increase in achievement in a cohort of postsecondary physics students after undertaking a flipped approach. However, as was the case with Ruddick (2012), the instructors in Deslauriers et al.'s (2011) study were different, again introducing the changing teacher variable. The instructors' differing natures could have played a role in influencing the research's outcomes.

Nonetheless, while these studies show promise for the flipped classroom to improve academic results, it highlights a need to control for certain variables (i.e., teachers and access to resources/pedagogy) to ensure appropriate comparisons can be made when discerning the effectiveness of pedagogical approaches. Furthermore, while the abovementioned studies highlight the positive potential for the flipped classroom in scientific disciplines, the literature further demonstrates the success of a flipped approach in mathematics. Fulton (2012) provided a mathematical perspective, highlighting the improvement to learning for students in Grades 9 to 12 in the United States as a result of implementing a flipped approach in mathematics. Fulton (2012) cited increases to student achievement in unit assessments for algebra and geometry, alongside increases to mathematics scores on standardised external exams for students who had participated in a flipped classroom (when compared with students who undertook the regular approach). Finkel (2012) also reported the positive impact that a flipped approach had in a school within his district, observing the failure rate for mathematics students (aged around 15 years; Year 9 equivalent in the Australian system) to drop from 44% to 13% in one year, following a flipped intervention. In the same period, they also observed the junior achievement (Australian equivalent of Year 11) to improve by 10% over the previous year.

While Fulton's (2012) and Finkel's (2012) observations are helpful in providing weight to the argument that the flipped classroom supports mathematics learning, larger scale empirical research has been designed and implemented that reinforces these observations. Kay and Kletskin (2012) used a sample of 288 first-year undergraduate students enrolled in a calculus course at a Canadian university to investigate the impact of implementing podcasts to teach pre-calculus concepts. They made 59 self-created problem-based video podcasts available to their students, covering five key areas in mathematics: operations with functions, solving equations, linear functions, exponential and logarithmic functions, and trigonometric functions. These podcasts were made available over a 21-day period to supplement what was covered in class and to help better prepare students for testing. Students rated the use of the problem-based video podcasts as effective in helping them to understand new material and self-reported significant pre-calculus knowledge gains as a result. Along with student self-reported increases to knowledge, the authors reported significant gains from pre- to post-test scores for all five categories of knowledge assessed, with an effect size considered to be between moderate and large. However, given there were no comparisons made between different groups (i.e., students who used podcasts and those who did not), it is difficult to distinguish if the podcasts contributed anything further to student learning that would not have otherwise taken place in a traditional format. The work of Sahin et al., (2015) added further insight to support reports of improved learning outcome. Through a case study approach in a college calculus course, they investigated the achievement of students who had undertaken a flipped learning approach. Overall, they reported an increase in student achievement (measured by calculus quiz scores) for students who undertook a flipped learning model when compared with traditionally taught sections of the course. They attributed this increased achievement to be the flow-on ability of the flipped approach to allow for more opportunities in the face-to-face classroom for students to interact with their peers and instructor than when compared with traditional lectures, a similar conclusion to that made by Bergmann and Sams (2009).

Lo et al. (2017) in a meta-analysis of 21 studies found a significant effect for improvement to student understanding in the flipped classroom over the "traditional" classroom in mathematics education. Lo and colleagues (2017) defined the traditional classroom in this context as one "where teachers use a range of strategies such as lectures, student group work and presentations, and then the students complete most of their homework after school" (p. 56). However, the authors noted that the investigation was hindered by most synthesised studies not clearly describing the question types used to determine student understanding or achievement. Furthermore, of the 21 studies, only two provided detailed information about the types of questions asked in pre- and post-testing measures. Their analysis, then, was reliant upon reported test scores rather than "understanding". Provided in their advice for future research was the need for researchers to indicate the types of questions they used to assess student achievement. This advice accentuates the recurring theme in the flipped literature, with differences in final exam scores used to exemplify differences in achievement—yet with no explanation of the types of questions in these exams. Additionally, and despite a favourable conclusion for the flipped classroom, the context studied (combined results for K–12 and higher education) did not separate or make adjustments for the context-specific nature that could exist in a flipped approach at different levels of schooling (i.e., differences at primary, secondary, or higher education levels). It is necessary, therefore, to delve deeper into the literature, alongside the method employed and the context in which it was delivered, to understand in more depth the impact of a flipped approach for learners in a secondary school environment.

While the abovementioned research has been able to demonstrate positive impacts on student achievement, it has done so through primarily university (higher education) level settings. While Lo et al.'s (2017) meta-analysis included some secondary education, they too noted a "paucity of research in secondary" (p. 55) education. Akçayır and Akçayır's (2018) review of the flipped classroom literature highlighted this ongoing paucity of research in secondary education, with the majority of the reviewed studies in their research conducted at a higher education level. Specifically, they noted that of the 71 studies reviewed, only 16% were focused on K–12 learners. While the positive potential of flipped learning for student understanding is highlighted by these studies, the generalisability of results from nonpostgraduate environments can be called to question,

The work of Love et al. (2014) contributes to the limited available literature at the secondary school level. Through a quasi-experimental design, they compared the results of sophomore-level students (Australian equivalent to Year 10) enrolled in an applied linear algebra course over one semester. These students were allocated arbitrarily to two classes: One received their instruction via a traditional lecture (n = 28) and the other undertook the flipped classroom (n = 27). The same teacher taught both classes and created the flipped content, which consisted of screencasts that mirrored the content covered through the traditional lecture sections. The classroom time for the flipped group was then reserved for engaging students in working on related problems. Throughout the semester, all students were expected to sit three common midterm exams and a comprehensive final exam. When the researchers compared the performance on the second exam relative to the first exam, they found the average change in score for students in the flipped group significantly greater than that in the traditional lecture group. Similarly, when comparing the third exam relative to the first exam, they again observed a greater average change in score for those in the flipped classroom group than for those who had undertaken the traditional lecture group. This certainly points to a positive impact from the implementation of a flipped classroom. However, these observed differences did not continue for the end-of-semester comprehensive exam. Despite greater performance in the midterm exams for flipped students throughout the semester, the authors reported no statistically significant difference in scores between the flipped group and the traditional lecture group on the comprehensive final exam (raw scores of 89.5 compared with 87.4, respectively). This, therefore, raises questions about the long-term efficacy of the flipped classroom and the retention of observed gains in a flipped classroom.

While no difference in the final exam results is intriguing, it is again pertinent to highlight a potential confounding variable in the design of Love and colleagues' (2014) study that could have contributed to such results. The traditional lecture group also had access to the flipped content, and therefore it would be reasonable to speculate that access to these additional resources could confound the final results. Nonetheless, they did initially observe a significant increase to achievement in the flipped group when comparing test results throughout the semester, and these differences were no longer apparent after the end-of-semester exam. Despite the potentially confounding variables, such a finding posits questions concerning retention of the observed differences, both in their study and all the abovementioned studies that noted changes but which had no follow-up observations to determine their longevity. Further controlled research studies are warranted to provide further insight into the longevity of differences after testing.

Alongside noting differences to group outcomes, there has been research into the achievement of learners with differing levels of mathematics ability. Through their investigation into the effectiveness of the flipped classroom on achievement in the topic of trigonometry, Bhagat et al. (2016) reported the performance of 82 high school students with different achievement levels. They identified and classified students as low, medium, and high achievers based on a pre-test and then subsequently remeasured their achievement through a post-test 6 weeks later. Students were assigned to a control group (n = 41) who underwent their teaching in the teacher's regular mode of instruction, consisting of 50-minute lessons separated into 30 to 40 minutes of lecture and discussion and the remaining time used for students to complete textbook problems. Students in this group were expected to complete homework that involved finishing the assigned textbook questions. The experimental group (n = 41) received their instruction through watching 15- to 20-minute videos before class. Their in-class time was then reserved for working on activities based on the instructional content of the videos. Students in the flipped group were also divided into groups to discuss the textbook problems, with students who required remedial assistance given face-to-face support. Following the 6-week intervention, students in the low achiever category in the flipped classroom were found to have outperformed their counterparts in the control group. This improved performance was attributed to the flipped classroom pedagogy providing more attention to the lower achieving group. The additional attention provided to lower achieving students in the flipped group through targeted remedial assistance in class could have contributed to the improved results for the flipped group given these opportunities were not afforded the control group. This helps to highlight the need to control for in-class activities between groups when attempting to determine the impact of the flipped classroom pedagogy in the absence of other intentional changes to in-class structures.

2.5.2 Flipped Classroom Does Not Improve Student Achievement

Not all empirical evaluations of the flipped classroom have been able to consistently demonstrate improvement to student achievement when compared to nonflipped groups. In response to the limited available literature at a secondary mathematics level, Clark (2015) designed an action research study to analyse the impact of a flipped learning approach in two algebra classes. A total of 42 Grade 9 students prepared for classes by watching videos, listening to podcasts, contemplating relevant topic questions, and viewing presentations. Class time was used for hands-on activities, participation in real-world applications, and independent practice in their teacher's presence. The flipped content in this study focused on solving and graphing systems of equations and systems of inequalities over a 7-week intervention period. Students' post-test performance in his flipped class was compared with students who participated in a nonflipped class. It is not clear who taught the nonflipped approach (i.e., if it was the same teacher as the flipped) or if students were compared in the same academic year (i.e., historical data from previous years being referenced). Nonetheless, no significant difference was reported in the post-test results of the flipped and nonflipped groups (mean scores of 80.38 and 80.0, respectively). This finding led Clark (2015) to conclude that flipped instruction may not be the best mode of pedagogy for increasing student performance in high school algebra. However, given that the focus of comparison was solely on a post-test, there was no indication that any of the pedagogical approaches were any more effective than others were at improving student understanding.

Research has also shown students in traditional lecture-based approaches to outperform students who have participated in a flipped approach. In an undergraduate semester-long statistics course, Gundlach et al. (2015) reported higher average scores for the students in a traditional group (n = 330) for all three of their assessed exams when compared with a flipped group (n = 56). This difference was determined statistically significant for two of the three exams, with traditional students performing 5.22 and 4.64 points (of 100) higher for Exams 1 and 2, respectively. The authors speculated the improved performance of the traditional group in this instance to be the result of their enhanced lecture-based strategies that they felt kept students engaged. Through their discussion, they signalled the lack of clarity in the literature when "traditional" lectures are used in flipped classroom research and called for authors to be more explicit when defining their traditional teaching to make appropriate comparisons. This again returns to the point made throughout this thesis for the need for clarity and control of pre-class or in-class activities such that appropriate comparisons can be made between research.

Kennedy et al. (2015), who investigated the effect of a flipped approach during a semester-long university calculus course, reported a similar, yet statistically significant, finding. The same instructor taught four separate classes, with a total of 173 students involved. Two classes were taught using a traditional lecture-based format (control group, n = 86), and the other two classes were taught through a flipped pedagogy (experimental group, n = 87). Students in each class were given a pre-test and were assessed through four midterm exams and a final exam. The questions in these assessments had both a computational nature to them (i.e., calculation using a provided algorithm) and a conceptual nature (i.e., application or an extension of knowledge from a known formula). Interestingly, despite no significant differences in pre-test scores, the authors found a significant difference in exam scores between the control and experimental groups, with the control group significantly outperforming the flipped group (4.4 percentage points difference). Of particular interest was that their study noted a significant difference in the conceptual component subscore, with the control group outperforming the flipped group by 6.3 percentage points. The authors concluded, “Perhaps inverting a classroom might not be the best pedagogy to use with conceptual material” (p. 13).

Kirvan et al. (2015) provided further insight on student understanding of linear equations at the high school level through their research involving a combined group of Grade 7 (n = 8) and Grade 8 (n = 46) students in the United States. After random assignment to either a flipped (n = 25) or control (n = 29) group, students undertook a 12-item pre-test relating to three factors of systems of linear equations (analysing, modelling, and solving). The pre-test established no significant differences between the two groups, confirming a similar base of understanding before the intervention. The teaching intervention followed, involving the control classroom taking a “business-as-usual” approach to learning, which consisted of 10 to 15 minutes’ direct instruction with guided notes. The flipped classroom received their instruction at home through online instructional videos, ensuring, “The only difference between the groups was the flipped classroom procedure” (p. 208). However, the authors did note a disparity in their lesson delivery, with the flipped group having more opportunity to undertake enrichment activities due to the enhanced efficiency of initial content delivery. Following the intervention period (duration unstated), the authors found no significant differences between the flipped and control groups in their understanding of linear equations. While Kirvan et al. controlled for students’ in-class experience and in-class structure, the control group was availed access to all lesson material, including flipped content. Furthermore, the control group was directed to use the videos as make-up work after being absent for any lessons. The use of flipped content in the control group may have contributed some treatment diffusion between groups, which may have contributed to the lack of observed significant differences.

DeSantis et al. (2015) used a flipped approach for high school students in the United States for a lesson on points of concurrency. Both the flipped (n = 21) and control (n = 26) group undertook a pre- and post-test assessment to ascertain knowledge before and after the intervention. The resulting statistical analysis found that the flipped approach was no more effective than a nonflipped approach for developing student understanding of points of concurrency. The research concluded that the replacement of lecture-based content with video was unlikely to be the mechanism responsible for any previously reported success of the flipped classroom. Instead, they noted that flipped classroom efficacy was highly dependent on the skill of the teachers who employed it and “their abilities to marshal their resources to devise lessons that meet the learning needs of their students” (p. 52).

Bhagat et al. (2016) considered the notion of devising lessons to suit learners’ needs, mentioned in Section 2.5.1. They designed and implemented targeted lessons for low achievers during the in-class components to improve their results, and this could perhaps explain the differences in achievement between the two studies. Further supporting the need to design purposeful lessons is Jensen et al.’s (2015) finding that the in-class components of a flipped classroom could be the defining aspect to its success. Moreover, their research highlighted that it is perhaps the classroom activities that are more important than the classroom flip itself. Through a quasi-experimental design, Jensen et al. (2015) compared the achievement of a nonflipped (n = 53) and a flipped (n = 55) cohort in a university-level unit of biology. Both the flipped and nonflipped groups utilised an active-learning, constructivist (i.e., inquiry/discovery based learning; see Section 2.4.2) approach to learning in the classroom, and upon conclusion of the unit, the authors found that the learning performance for each group to be equal. Given that both classrooms utilised the same in-class approach, the authors suggested that the success of the flipped classroom be attributed to the active learning that took place in class instead of the classroom flip itself. This suggestion certainly highlights the need to ensure all variables are considered in the design and subsequent analysis of the research to ensure that any causal influence of the flipped classroom on student achievement is not confounded by large differences in activities between the classrooms being compared. This finding also serves to highlight the need to understand how the teacher uses their class time when they have utilised a flipped approach so that appropriate comparisons can be made between research studies that discuss flipped approaches.

Moreover, in the literature, criticisms continue to call for "more stringent study designs" with "complete and accurate reporting" (Låg & Sæle, 2019, p. 14) in response to the varied implementation of flipped classrooms. In particular, studies should report and control for as many aspects of the flipped classroom as possible to help determine the unknown mechanisms that "may work very well in some situations and be less effective in others" (p. 14). Låg and Sæle's meta-analysis also revealed a subject-specific impact of the flipped classroom, with humanities appearing to benefit the most and STEM-based (science, technology, engineering, and mathematics) disciplines the least. However, pertinent to note again is that of the 272 studies examined as part of this analysis, only 22 were in the secondary education environment.

Nonetheless, both empirical and non-empirical studies have demonstrated some capacity for the flipped classroom to influence, one way or the other, student achievement or outcome. However, the generalisability of this influence on achievement remains questionable for Australian secondary school contexts given the majority of the research took place in international higher educational settings. The relative contributing differences in culture, attitude, and motivation factors that could exist between international higher educational settings and an Australian secondary school environment should not be overlooked in their capacity to play a role in the success of a flipped approach. Furthermore, given recent research has indicated a subject-specific efficacy of a flipped classroom (e.g., Låg & Sæle, 2019), there is an added difficulty in generalising flipped classroom research that has been conducted outside mathematics contexts. The need for further controlled, data-driven studies in mathematics and Australian secondary classrooms is warranted to further understand its impact in these contexts.

2.6 Flipped Classroom and Student Attitude

While the previous sections have considered student academic achievement, this section focuses on student attitude, which can also have an influencing role in student learning. Wigfield and Eccles (1992, 2000) highlighted the importance of this in mathematics with their EVT, which demonstrated the influence of student affective response on subsequent academic achievement and a continued interest in mathematics. Their research and ensuing framework highlight that attitude can play a long-term influencing role to a host of factors, including future academic achievement, and while not immediately observable in the short run, attitudes can profoundly impact achievement in the long term. Similarly, the work of Pierce et al. (2007), discussed in Section 2.2, highlights the potential for improvement in mathematics learning that could result through the increased affective dispositions of students in mathematics and the heightened impact of this when technology is involved. Student attitude is, therefore, crucial when considering future learning outcomes in mathematics. The literature relating to the flipped classroom demonstrates a wide range of student attitude responses in the transition to a flipped classroom, and this section details the results of such studies within a range of educational contexts.

2.6.1 Flipped Classroom Improves Student Attitude

The literature supporting the notion of improved student attitude in response to the flipped classroom implementation is presented in this section.

Through pre- and post-survey data of 42 Grade 9 students in the United States, alongside focus interviews with 12 randomly selected students, Clark (2015) determined student perception of a flipped intervention for a cohort of students learning algebra. Through analysis of the survey data after the 7-week intervention, he observed an increased tendency for students in the flipped cohort to move from *agree* to *strongly agree* for items relating to student involvement in class and desire to learn course content (i.e., increased engagement). Furthermore, thematic analysis of the interview data revealed an increase in classroom participation and enjoyment of content for students who had experienced the flipped classroom. Similar improvements to attitude were found by Love et al. (2014), who observed that sophomore-level students (Australian equivalent to Year 10) in the flipped cohort, on average, indicated higher levels of satisfaction with their learning and greater enjoyment of linear algebra when referenced to their peers in the traditional lecture setting. Given that both Clark's (2015) and Love et al.'s (2014) research was on high school-level mathematics, the improvement to student attitude in each study bodes well for the flipped classroom implementation in secondary mathematics.

Guerrero et al. (2015) provided further evidence of favourable attitude in the flipped classroom for students in an undergraduate finite mathematics course. Through pre- and post-survey data collected at the start and end of the semester, they observed a significant increase in student attitude towards mathematics (enjoyment in mathematics—i.e., affective engagement) in their flipped group (n = 23) when compared with the traditional group (n = 24). While this increase was not significant across all other measured affective variables (i.e., self-confidence and motivation), it does highlight that the flipped classroom can positively influence student attitude.

While the three abovementioned research studies were conducted in the United States, Muir and Geiger (2016) conducted a case study of an Australian Year 10 mathematics class (N = 27) to understand the impact of a flipped approach. Students self-reported their experiences in the flipped classroom and contrasted these with their previous years of experience in nonflipped classes. Muir and Geiger found a tendency for students to indicate a positive flipped classroom experience—evidenced by a heightened engagement towards completing mathematics tasks. This case study begins to shed light on the situation for secondary-aged students in Australian contexts; however, given it was reliant on historical data (i.e., students referencing experiences from previous years in nonflipped classes), without a comparison group, it is difficult to account for maturational threats to validity within these data. Nonetheless, these abovementioned studies, along with others throughout the literature (e.g., Chao et al., 2015; Muir & Chick, 2015; Ruddick, 2012), begin to highlight a similar effectiveness of the flipped classroom in producing positive student affective outcome.

2.6.2 Flipped Classroom Does Not Improve Student Attitude

In contrast to the demonstrated improvements to student attitude presented in the previous section, this section presents the literature supporting the notion that the flipped classroom has either no, or detrimental, impact on student attitude.

Strayer (2012) compared two introductory university-level statistics classes over a semester, one flipped (n = 23) and the other a traditional lecture (n = 26). In the final 2 weeks of the course, students completed written surveys, with focus interviews with selected participants, to determine students' perceptions of their current learning environment and their opinions on their ideal learning environment. Strayer found a negative attitude from students in the flipped group. In particular, Strayer highlighted that the flipped group had an increased propensity for students to appear “lost” in the new classroom expectations and a subsequent higher likelihood to disengage from material sooner than students in the traditional lecture group. These results prompted Strayer to conclude that a flipped classroom may not be the preferred design for an introductory-level course. This conclusion was largely built on the notion that many students who enrol in an introductory course are not likely to begin with a deep interest in the subject and therefore may become frustrated if they encounter learning tasks that are not clearly defined. Strayer’s conclusion, when considered alongside findings of later research, some of which has shown students to find instructional videos to become “boring” (e.g., Muir & Chick, 2014, p. 491), could pose a problematic scenario for the flipped classroom at the secondary school level, where students may not have yet developed a deep interest in mathematics.

Moreover, despite Guerrero et al. (2015) observing statistically significant positive student attitude towards mathematics in their flipped group, they did not observe an increase to all affective variables measured (i.e., motivation and self-confidence). Furthermore, their analysis of open-ended survey data revealed that students’ positive attitudes were progressively declining towards the end of the semester. In particular, they found, “The number of students who viewed video lectures positively dropped and the number of students who viewed video lectures negatively increased” (p. 826). This finding begins to highlight a potential transient nature to the impact of favourable perceptions in the flipped classroom.

More recently, Lo and Hew (2017), in a review of 15 empirical studies from four countries relating to K–12 classroom environments, concluded with mixed results for student attitude after a flipped approach. The review included studies from the United States (n = 7), Taiwan (n = 6), Canada (n = 1), and England (n = 1), spanning a range of disciplines (science, technology, engineering, mathematics, social studies, Chinese, English, and health education). While there was an acknowledgement that some students had favourable attitudes after a flipped approach, there were also reports of negative student attitude. In particular, some students commented that the process of watching videos and learning through a flipped approach was not an enjoyable activity. These comments highlight the negative attitudes discussed earlier by Guerrero et al. (2015) and begin to signal some inability for a flipped approach to impact positively (or at all) on attitude for some students.

The research that has indicated negative student attitude could be further concerning at the secondary school level. In a secondary mathematics classroom, students are often exposed to introductory concepts that are progressively built on through their time in school. In that environment, students may not have developed the required passion or motivation to be successful in aspects of mathematics and persevere through "boring" videos, which could jeopardise future learning and engagement. Guerrero et al. (2015) highlighted a similar point, noting a propensity for students to disengage with the online videos and grow "fatigued with the same pedagogical approach day after day" (p. 826). There is a need to seek clarification concerning how students perceive a flipped classroom. Furthermore, with the limited available research in secondary classrooms, further investigation is warranted in this area to help make claims on the impact of a flipped approach in a secondary school mathematics classroom.

2.7 Flipped Classroom and Teacher Experience

A flipped classroom can call for a substantial shift in the way teachers plan and prepare for classes (Roehl et al., 2013; Speller, 2015). These demands can ultimately command a greater amount of preparation time—even for the most experienced teachers (Akçayır & Akçayır, 2018; Bergmann & Sams, 2016). This section explores the available literature relating to teachers' experiences in their flipped classroom implementation.

The increased teacher workload required to create flipped lessons has been considered a major problem of the flipped approach (Lo & Hew, 2017), with some research reporting 70+ working hours to redesign courses under a flipped approach (e.g., Adams & Dove, 2016). However, there is evidence to suggest that the return for both students and teachers is worthwhile (Brunsell & Horejsi, 2013; Speller 2015). Through surveying the 15,000 members of the National Center for Case Study Teaching in Science, Herreid and Schiller (2013) set out to investigate if (and subsequently, how) STEM teachers were using the flipped model. They found 200 teachers had used a flipped classroom, and that generally, teachers found it to be an enjoyable and worthwhile pedagogical approach.

It has been postulated that the flipped classroom makes it easier for teachers to provide accommodations and modifications in the classroom for students with individualised educational plans, catering to each student's educational needs (Finkel, 2012; Fulton, 2012). After implementing the flipped classroom in her school, Fulton (2012) observed teachers feeling as though they had more time in class to work with students and subsequently better ability and insight to address student difficulties and learning styles. Fulton's observations are not unique, with Finkel (2012) finding that after a flipped implementation in his school district, the teachers appreciated the more regular opportunities for differentiation availed through the flipped classroom approach and subsequently wanted to continue with it. Speller (2015) discussed the similar abovementioned flow-on effects from the implementation of a flipped classroom, concluding a positive response from the six teachers in their study, who indicated they would continue using the approach.

However, flipped classroom implementation has also generated negative teacher feedback. Johnson and Renner (2012) highlighted the perspective of one teacher, who found the workload required for planning the flipped classroom cumbersome. This teacher thought of each lesson as requiring two lesson plans that needed to be prepared—that is, a pre-class and an in-class plan. This notion of increased workload when implementing a flipped classroom is also a view expressed by teachers in other research. Wanner and Palmer (2015) concluded that increased workload was the largest concern shared by the 47 university teachers who participated in the implementation of a flipped classroom in an Australian postgraduate course. In particular, these teachers reported additional time commitments that were required to set up, implement, and manage a flipped classroom. Through survey responses, one teacher detailed that preparation that would usually take 1 hour for a lecture now consumed 6 hours. More recently, Akçayır and Akçayır (2018) reviewed 21 research studies, reporting one of the challenges of implementing a flipped classroom to be the significant start-up effort required by the instructors. Through an in-depth look at this challenge, they found teachers' most common complaint to be the large amount of time required to create and edit video lectures in addition to preparing in-class activities.

While the majority of these studies were set primarily in international or higher education environments, it appears widely recognised that flipped classroom implementation is coupled with a higher workload. While some teachers have found a positive trade-off to this time (i.e., more targeted in-class activities), others have seen it as burdensome with no real rewards (e.g., Johnson & Renner, 2012). Further investigation on the impact of a flipped classroom for a secondary school teacher will contribute additional insights on the efficacy of the approach.

2.8 Significance of This Doctoral Research

Several researchers have emphasised caution when interpreting the impact of flipped learning (e.g., Abeysekera & Dawson, 2015; Bishop & Verleger, 2013; O'Flaherty & Phillips, 2015). In signalling this caution, an explicit call for more evidence-based practices has been made to further evaluate the contribution of a flipped approach to teaching and learning (Love et al., 2014). The aforementioned (Section 2.5) meta-analysis of 21 studies in mathematics education (Lo et al., 2017) and other larger scale reviews involving a variety of different settings and subjects (Akçayır & Akçayır, 2018; Låg & Sæle, 2019) highlight that work is ongoing for understanding the efficacy of a flipped approach, and research needs to expand to support this. In particular, and parallel to the call for future research, it should be reemphasised that a significant portion of the flipped classroom literature continues to be dominated by international postgraduate environments, with limited focus on Australian or secondary education environments in general. The predominately studied international higher education environments, which present with different curriculum and culture to those of an Australian secondary school environment, may impact the generalisability of results to a mathematics curriculum in an Australian secondary school context.

While the need for more empirical data-driven studies is signalled through the literature for flipped learning in general, specific requests for research in K–12 environments have been emphasised (e.g., Lo & Hew, 2017). Further research would help substantiate the potential benefits a flipped approach could offer about student understanding and attitude, particularly in an Australian secondary school context. The current doctoral mixed-methods case study will contribute data to aid the understanding of a flipped classroom approach in an Australian mathematics classroom. In the next chapter, the practical implications of implementing a flipped classroom, alongside the impact on student attitude and understanding in solving linear equations, are discussed. Furthermore, the experiences and perspectives, as outlined by the teacher when shifting to this mode of pedagogy, are explored.

Chapter 3.

Research Design and Methodology

This chapter describes the methodological bases (Section 3.1) and the setting of this doctoral research (Section 3.2). An explanation of the process and justification for the recruitment of participants then follows (Section 3.3), before elaborating the experimental design of the research (Section 3.4). The justification and explanation of each of the instruments used in this research to determine student understanding (Section 3.5) and student attitude (Section 3.6) is then presented, highlighting how data were collected using these instruments. The teacher participant's involvement in the flipped classroom, along with the structure of the semistructured interview timeline, is then outlined (Section 3.7), providing insight into the teacher's involvement in the flipped classroom and the process of data collection for teacher experience and perspective. Section 3.8 then describes the specific method of data analysis of each instrument for each aspect of the research (i.e., student understanding, attitude and experience, and teacher experience and perspective). Finally, the limitations in the research design are highlighted through Section 3.9 to acknowledge the theoretical boundaries of this research.

3.1 Methodological Bases

The purpose of this doctoral research was to compare the impact of a flipped classroom approach when teaching students to solve linear equations. Comparisons were made between two classes, taught by the same teacher, measuring student understanding, student attitude and experience, and teacher experience and perspective. The teacher used a flipped classroom approach to teaching with one class, while the same teacher taught the other class using their regular approach to teaching. The explanations and examples used to teach the topic were planned to be the same for each class, with the delivery of instruction the only planned difference (see Section 3.7.2 for comparisons between class structures). Having the same teacher as a constant between both classes was important in helping to control the potential variability that two separate teachers could contribute to the results through their inherent differences in approach to teaching and student rapport (see Section 3.3 for further information).

One of the aims of this research was to identify the understanding that students in each of the two classes demonstrated when solving linear equations and how the flipped and regular groups' understanding compared at three separate time points. The first time point for comparison of understanding before teaching the linear equations topic was to ascertain students' baseline understanding before any teaching or intervention. The second time point was at the end of the 4-week topic to determine any differences from initial testing (i.e., changes in understanding). The third and final time point was approximately 3 weeks after the second time point to determine any retention in understanding. This research also sought to compare and analyse five affective variables (attitudes) related to students learning mathematics across the flipped and regular instruction classes. Students' attitudes were measured before teaching the topic to provide baseline data and again at the end of the 4-week topic to determine any differences in attitude. Students' perceptions of how they felt about the flipped classroom and their experiences in using a flipped classroom to learn were captured at the end of the 4-week topic. Finally, this research gathered and analysed the teacher's experiences of planning and implementing a flipped classroom and their perspectives on what they observed in their classroom as a result.

A mixed-methods approach was undertaken to address the abovementioned aims, with both qualitative and quantitative data collected and analysed. The data for this research were generated through student pre- and post-topic self-reported surveys, student pre- and post-topic testing, and teacher interviews, which are explored in more detail through the ensuing sections.

3.2 Setting of Study

The setting for this research was the researcher's place of employment, School A. School A is a co-educational secondary school, and the research was undertaken with two classes of Year 9 mathematics students. The Year 9 students in each class were allocated eight 50-minute lessons of mathematics per fortnight, with most lessons delivered in "doubles" of 100 minutes (i.e., two x 50-minute lessons back-to-back). Mathematics was a mandatory subject for all students of School A, and each student undertook the same standard mathematics curriculum at Year 9, regardless of ability, motivation, or aspiration to do so.

This research focused on one teacher's two mathematics classes in Year 9 as she taught them to solve linear equations. Kate (a pseudonym for the teacher participant) nominated one class to receive their instructional content using a technology-enabled flipped learning approach (experimental group). The other class received Kate's regular approach to teaching and learning (control group).

School A utilised a 1:1 MacBook program, whereby each student was issued with an Apple MacBook upon entry to Year 7 for their use at school and home until the end of Year 10. All teachers in School A were also issued with an Apple MacBook and had access to various tablets and other forms of technology that they could utilise for general planning purposes.

School A's mathematics curriculum followed the Year 9 Victorian Curriculum (VCAA, n.d.) as described in Section 1.2. The mathematics faculty at School A had a common teaching and learning program for each topic at each year level. These lessons were sequenced into 50-minute lessons that outlined the lesson structure and teaching points that covered the appropriate content to address the curriculum. Students typically used their MacBook in mathematics to access an online version of the prescribed textbook and complete any assigned exercise questions in their handwritten workbooks.

3.3 Recruitment of Participants

This section outlines the recruitment of participants for this research. Permission from three levels of participants was sought (i.e., school, teacher, and student), and these are discussed below.

3.3.1 School Recruitment

Human ethics approval was sought and granted from the University of Melbourne to conduct this study (Ethics ID: 1750414.1). Following ethics approval, permission was sought and granted from Catholic Education Melbourne to conduct research in a Catholic school (see Appendix A). To secure student and teacher participation for this study, the purpose and rationale were discussed with the principal of School A, who was provided with a plain language statement and consent form (see Appendix B).

3.3.2 Teacher Recruitment

After the principal's consent was obtained at School A, a teacher participant was sought. Through the 2018 school year, School A scheduled regular professional learning workshops that afforded time and expertise to teaching staff to build on their professional practice. Teachers could select specific workshops that suited their interests, with one workshop dedicated to flipped learning, which was facilitated by the researcher. The teachers from the mathematics faculty who were participants in the flipped learning workshop were invited to participate in this research. Given that the same teacher for both classes would help to control aspects of variability in teaching approach when making comparisons, the benefit of having two classes at one year level was outlined to the invited teachers. This was important, as different teachers between classes may introduce additional extraneous variables to the data through their inherent teaching differences—that is, general variability in their relationship and rapport with students, their understanding and approach to content, their classroom environment expectations, and their general demeanour. Attempting to control for such variability through having the same teacher helped to ensure an equal comparison between the results of the flipped and regular classes. One teacher who taught two classes at Year 9 subsequently volunteered to be part of the study. This teacher was provided with a plain language statement and consent form to declare their informed consent to participate (see Appendix C).

3.3.3 Student Recruitment

Kate was asked to nominate one of her classes as the experimental group and the other as the control group. The students in each group were provided with a plain language statement and consent form during a mathematics lesson (see Appendices D and E). Students were informed both verbally and in writing that their participation was voluntary. If they agreed to participate, they returned the consent form with their signature along with their parent's or carer's signature.

3.4 Experimental Design

This section outlines the design considerations of this doctoral research, including justification of its quasi-experimental design. The potential threats to validity are then discussed, alongside the controls in place to help reduce the impact of these threats in this research. Finally, the specific time points for each phase of data collection are outlined and discussed.

3.4.1 Quasi-Experimental Design and Threats to Validity

Walser (2014) cited the logistical issue of having to randomly assign students to control or experimental groups in a school setting as one of the primary reasons for the lack of "true experimental research" within educational settings. However, there is good reason for this. In a typical school environment, it is difficult to randomise students to a particular intervention given that they are already grouped in timetabled classes. A quasi-experimental design, therefore, allows the ability to measure the effect of changing an independent variable (i.e., pedagogical approach) and to determine the subsequent response of the dependent variable (i.e., student understanding and attitude), without disruption to the normal day-to-day operation of the school. Students remain in their usual classes, with the intervention applied to previously established groups. Quasi-experimental designs, therefore, allow more natural observations of cause and effect to be observed.

Campbell and Stanley (1963) first emphasised the caution researchers should exercise when considering a quasi-experimental approach given the issues inherent in nonrandom assignment to groups. Specifically, they outlined the need to understand the ways a "worthy" quasi-experimental design can be implemented when true or randomised experiments are not feasible. In particular, they outlined eight extraneous variables that are considered "threats to internal validity" in experimental designs. These, if not appropriately controlled for, can produce effects confounding the effect of the experimental intervention. These potential threats were addressed in this doctoral research through the design phase to ensure appropriate claims to validity could be made. The way this doctoral research design accounted for each threat is outlined in Table 3.1. The external threats to validity are discussed through the limitations of the research in Section 3.9.

Table 3.1

Explanation of Controls for Internal Threats to Validity

Threat to Internal Validity	Explanation of Threat	Response to Control for Threat in This Research
History	Specific events that occur between measurements that influence outcomes	This research has a two-group design. The control group was the same year level, learning the same topic with the same teacher. They were observed for the same duration as the flipped group at the same time intervals.
Maturation	Changes due to normal developmental processes for the research participants	This research has a two-group design. Given students in each group were similar-aged students and were observed over the same time period and in the same school year, any maturation changes that could occur for student participants in one class were assumed to be similar to those in the other class.
Instrumentation	Changes in the instrument, researchers, or measurement devices that could produce changes to observed outcomes	The testing instruments and conditions for each understanding assessment (Quizzes A, B, and C) were identical for both the regular and flipped groups. Each group was given the same time limit to complete these tasks. The attitude survey (MTAS, explained in Section 3.6) was also identical, with the same conditions provided for both groups to complete this.
Regression to the mean	Selection of subjects on the basis of previous extreme scores or characteristics	Both groups were previously established classroom groups, not selected for any extreme characteristic.
Testing	Pre-testing can "condition" participants in unanticipated ways, and this could impact the outcome	Both the flipped and the regular classroom group were exposed to the same pre-test, so any "conditioning" that may have occurred could be considered equal.

Threat to Internal Validity	Explanation of Threat	Response to Control for Threat in This Research
Selection bias	Due to sampling techniques, selected participants in the study were not equal to begin with	While random selection was not utilised, a pre-test was conducted to ascertain if there were underlying baseline differences between the groups before commencing the intervention, and growth was then measured as a reference to the pre-topic measure.
Experimental mortality	Loss of participants as the research was undertaken	The research was conducted in one school term in the same academic year, at the same time, for both groups. No extracurricular activities were scheduled during this time, and all students were required to be at school for the term. This assisted in maximising a constant population of students in the study from start to finish.
Diffusion of treatments	Improper treatment of the control group with the same treatment used as an intervention in the experimental group	Access to the flipped tutorials was only provided to the flipped group through a password-protected website. Content could only be streamed using the school-issued login credentials. While this did not preclude one student showing another student the content, it did add a layer of difficulty and inconvenience for a regular classroom student to access the flipped content.

3.4.2 Time Points for Data Collection

This study was a nonequivalent pre-test/post-test time-series design with a control group. A shorthand coding system that represents the experimental design diagrammatically is provided using established methods (Campbell & Stanley, 1963; Cook & Campbell, 1979). In this representation (Figure 3.1), "X" represents the intervention (flipped classroom) and "O" represents an observation (i.e., student quiz/assessment, survey, or teacher interview). Any "X" and/or "O" that appear above or below one another are measurements that were taken at the same time point. The student pre-/post-testing and survey data were conducted in the same lesson, for both groups, at the following time points:

Figure 3.1

Overview of Data Collection Time Points for the Flipped and Regular Groups

O	X	O	O	[Flipped]
O		O	O	[Regular]

Adding the teacher interviews to this, and coding as described in Table 3.2, the overall study design is set out in the following coding diagram (Figure 3.2). Table 3.2 also specifies the research instrument used at each time point, alongside the contribution of the collected data towards specific research questions of this research:

Figure 3.2

Specific Data Collection Time Points for the Flipped and Regular Groups

O_{INT1}	$O_{QA\&S1}$	X	O_{INT2}	$O_{QB\&S2}$	O_{INT3}	O_{QC}
	$O_{QA\&S1}$			$O_{QB\&S2}$		O_{QC}

Table 3.2

Significant Events and Instruments Within the Study

Symbol	Group/s	Timeline	Research Instrument	Data for Research Question
$O_{QA\&S1}$	Control Experimental	Before commencing linear equations topic	• (QA) Pre-test (Quiz A) • (S1) Student attitude pre-topic survey	1, 3
X	Experimental	Approximately 4 weeks of teaching intervention (14 consecutive lessons)	N/A	1, 2, 3, 4, 5
$O_{QB\&S2}$	Control Experimental	In the next lesson after topic completed	• (QB) Post-test (Quiz B) • (S2) Student attitude post-topic survey	1, 3, 4
O_{QC}	Control Experimental	Approximately 3 weeks after $O_{QB\&S2}$	• Delayed post-test (Quiz C)	2
O_{INT1} O_{INT2} O_{INT3}	Teacher	Before, during, and after teaching intervention	• Teacher interviews	5

Note. $O_{QA\&S1}$ refers to the data collection time point for Quiz A and the student pre-topic survey. $O_{QB\&S2}$ refers to the data collection time point for Quiz B and the student post-topic survey. O_{QC} refers to the data collection time point for Quiz C. O_{INT1}, $O_{INT2,}$ and O_{INT1} refer to semistructured teacher Interviews 1, 2, and 3, respectively.

3.5 Research Instruments for Student Understanding

Students in this doctoral research completed one pre-topic test and two post-topic tests. These instruments provided the data necessary to determine the student understanding of solving linear equations in the flipped and regular groups. The pre- and post-test (Quizzes A and B) were online assessments (SMART tests; see Stacey et al., 2011a) developed by mathematics education researchers and are further described in Section 3.5.1. These tests provided insight into the growth of student understanding before and after the linear equations topic. The final post-topic test (delayed test; Quiz C) was a pen-and-paper test, developed by the researcher to parallel the previous online pre- and post-tests, and this is discussed further in Section 3.5.2. The intention of Quiz C was to provide the 3-week retention of understanding data for both groups. The use, development, and rationale for Quizzes A, B, and C are explored further below.

3.5.1 SMART Test System

For the pre-test and first post-test (time points $O_{QA\text{-}S1}$ and $O_{QB\text{-}S2}$, respectively), this research utilised the Specific Mathematics Assessments that Reveal Thinking test system (also known as SMART tests). SMART tests were designed as an online assessment tool in primary and secondary school mathematics to help provide teachers with information about their students' understanding in key mathematics topics (Price et al., 2009, 2013; Stacey et al., 2012, Stacey et al., 2011a). The tests are accessible to teachers via the web link www.smartvic.com/teacher. The tests intend to provide teachers with a research-based diagnosis of their students' understanding in a range of secondary school mathematics topics (Stacey et al., 2011a). The website contains tests on 65 topics (Stacey et al., 2011a), nearly all of which have paired or parallel pre-tests and post-tests (termed Quiz A and Quiz B on the website). Each test involves minimal calculation and there is minimal typing required on the student's part, with an online calculator provided to students should they wish to use it. Two relevant linear equations tests applied to this study: Linear Equations—Solving (Quiz A) and Linear Equations—Solving (Quiz B). Both tests required students to enter their answers using a text field, and these tests are explained further in Section 3.5.1.1.

The SMART test platform automatically diagnoses a student's understanding based on the answers they submit, and reports this feedback to the teacher. Included in the feedback to the teacher is the diagnosis of a "stage of understanding", which ranges on a continuum from *no understanding* to *complete understanding*. In reference to these stages, Stacey and colleagues (2011b) state,

> If a student makes errors on the most basic items, his or her understanding will be reported as Stage 0. This will occur whether later more complex items are correct or incorrect. It will alert a teacher to a basic concept that is not understood.
>
> If a student makes errors only on more complex items, his or her understanding will be reported as a mid-ranking stage.

> For a student's understanding to be reported as a high stage, that student will have demonstrated understanding of all of the lower ranking concepts as well as those of the high stage. (para. 9)

Alongside the stage of understanding feedback, the SMART test also diagnoses the misconceptions or knowledge gap exhibited by a student, and these are explored in Section 3.5.1.1 in the context of Quizzes A and B—solving linear equations. The website also provides information to the teacher as to how they could address these stages, misconceptions, and knowledge gaps.

It should be noted that SMART tests do not rely on the percentage of correct or incorrect responses; instead, Stacey et al.'s (2011a) programming within the system determines each student's understanding. This programming looks at each answer in detail to determine what concepts have been mastered and whether there are any patterns in the wrong answers a student has given. For this reason, the raw percentage correct score for any test does not reliably indicate a student's stage as it depends specifically on which questions the student answered correctly and the pattern in their responses.

3.5.1.1 SMART Test: Linear Equations—Solving Quizzes A and B (Pre- and Post-Test)

The SMART tests used for this study were the Linear Equations—Solving tests. These were two parallel tests available on the SMART test website (Quiz A and Quiz B), each of which focuses on the same concepts and skills.

One of the tests was used as the pre-test (Quiz A; see Appendix F), and the other was used as the first post-topic test (Quiz B; see Appendix G). Both tests were designed to assess a student's ability to solve linear equations in one variable, the most complicated of which is the form $ax + b = cx + d$ (e.g., $4x + 6 = x + 1$). According to the authors, the time expected to complete each test is 15 minutes (Stacey et al., 2011a), and as such, students in this study were given a maximum of 15 minutes to complete each test in their regular class time. These tests provided the necessary data to respond to RQ1.

As discussed in Section 3.5.1, student understanding of solving equations is classified into stages after each test. The Linear Equations—Solving tests have stages ranging from 0 to 4, with a higher number stage indicating a higher level of understanding. The five stages and relevant descriptors for each Linear Equations—Solving test are shown in Table 3.3.

Table 3.3

Stage and Descriptor Information for the Linear Equations—Solving SMART Tests

Stage of Understanding	Descriptor
Stage 0	Students are unable to solve the simplest of linear equations, including those that are able to be solved through guess-and-check methods.
Stage 1	Students can solve simple linear equations that are easy to solve by guessing,
Stage 2	and can solve linear equations with more difficult answers so that a systematic method such as backtracking is required,
Stage 3	and can solve linear equations with pronumerals on both sides and only addition symbols, so that they need to be solved by "subtracting the same from both sides",
Stage 4	and can solve linear equations with pronumerals on both sides where constants and/or coefficients can be negative, so that they need to be solved by "doing the same to both sides".

Note. Adapted from "Developmental Stages and Teaching Suggestions" by K. Stacey et al., 2011a (http://www.smart-quiz.edu.au/teacher). Copyright 2011 by SMART research.

In addition to the above statements of understanding, for this research, the five stages were assigned qualitative descriptors (see Table 3.4), which are in line with Stacey et al.'s (2011b) stage descriptions. The four types of misconceptions and one knowledge gap (MKG) reported by the Linear Equations—Solving tests are each assigned an acronym for ease of reference, with these acronyms and descriptors referenced in Table 3.5.

Table 3.4

Qualitative Stage of Understanding Descriptors for the Linear Equations—Solving SMART Tests

Stage	Demonstrated Understanding
0	None
1	Basic
2	Developing
3	Complex
4	Complete

Table 3.5

Misconceptions and Knowledge Gap Descriptors for the Linear Equations—Solving SMART Tests

Misconception/Knowledge Gap	Descriptor
AES	Addition equation solution: These students, when given an equation of the form $x - a = b$, give the solution of the related equation $x + a = b$.
RES	Reverse equation solution: These students, when given an equation of the form $a - x = b$, give the solution of the related equation $x - a = b$.
BES	Bracketless equation solution: These students, when given an equation of the form $a(x + b) = c$, give the solution of the related equation $ax + b = c$.
SE	Simplification error: These students are unable to correctly gather like terms, which affects their ability to solve some types of equation.
AF	Algebraic fraction: These students are unable to solve equations of the form $x/a + b = c$ and/or $(x + a)/b = c$.

Note. Adapted from “Developmental Stages and Teaching Suggestions” by K. Stacey et al., 2011a (http://www.smart-quiz.edu.au/teacher). Copyright 2011 by SMART research.

Students in the experimental and control groups completed both Quiz A and Quiz B assessments, allowing relative pre- and post-test comparisons to be made to determine any change in student understanding following the teaching of the linear equations topic.

3.5.2 Pen-and-Paper Linear Equations Test: Quiz C (Delayed Testing)

A delayed test (O_{QC} measurement from Section 3.4) was implemented following the post-test to determine student understanding, misconceptions, and/or knowledge gap 3 weeks after the topic’s completion. Quiz C was a pen-and-paper test, with each question designed to parallel the same level of understanding required for success with Quizzes A and B. The student understanding from Quiz C was compared with the previous understanding demonstrated in Quiz B. This comparison provided an insight into the effectiveness of each teaching approach in being able to develop or retain student understanding and provided the data necessary to respond to RQ2.

3.5.2.1 Determining Stage of Understanding, Misconceptions and Knowledge Gap Data for Quiz C

This section explains how Quiz C was developed. Given Quiz C was a pen-and-paper assessment, there was no automatic diagnosis available through the SMART test website. An explanation of the method of analysis utilised to determine stage, misconception, and knowledge gap data based on a student's written response to Quiz C items is provided in this section.

Parallel items for Quiz C were produced by determining the understanding required to solve each Quiz B question and then replicating this with a similar question. The original items for Quiz B along with the parallel items for Quiz C are presented in Table 3.6.

Table 3.6

Parallel Items for Linear Equations—Solving Quiz B and Quiz C

Quiz B Item	Quiz C Item	Parallel Rationale	Stage of Understanding or MKG
$4n + 11 = 23$	$9p + 22 = 40$	- Both items of the form ax + b = c. - Both items can be solved by guess and check.	Stage 1
$3n + 5 = 26$	$5p + 16 = 66$	- Both items of the form ax + b = c. - Both items can be solved by guess and check.	Stage 1
$8n + 3 = 16$	$3p + 1 = 15$	- Both items of the form ax + b = c. - Both items require a systematic method such as backtracking to be solved.	Stage 2
$5n + 7 = 15$	$6p + 12 = 23$	- Both items of the form ax + b = c. - Both items require a systematic method such as backtracking to be solved.	Stage 2
$11n + 3 = 7n +16$	$14p + 11 = 5p + 12$	- Both items of the form ax + b = cx + d. - Both items require solving by subtracting the same from both sides.	Stage 3
$9n + 3 = 4n + 12$	$9p + 5 = 4p + 15$	- Both items of the form ax + b = cx + d. - Both items require solving by subtracting the same from both sides.	Stage 3
$7n - 11 = 2n - 4$	$9p - 13 = 4p - 6$	- Both items of the form ax − b = cx − d.	Stage 4

Quiz B Item	Quiz C Item	Parallel Rationale	Stage of Understanding or MKG
		- Both items require operating with negative coefficients solving by subtracting the same from both sides.	
$12 - 11n = 5 - n$	$17 - 16p = 10 - 5p$	- Both items of the form ax − b = cx − d. - Both items require operating with negative coefficients solving by subtracting the same from both sides.	Stage 4
$5n - 1 = 16$	$5p - 1 = 16$	- Both items of the form ax − b = c. - Both items provide the same opportunity for students to demonstrate AES misconception.	MKG (AES)
$15 - 2n = 9$	$20 - 2p = 16$	- Both items of the form b − ax = c. - Both items provide the opportunity to demonstrate RES misconception.	MKG (RES)
$2n + 4 + 3n = 5$	$2p + 7 + 3p = 6$	- Both items of the form ax + b + cx = d. - Both items provide the opportunity to demonstrate SE.	MKG (SE)
$\frac{n+1}{5} = 3$	$\frac{p+3}{7} = 2$	- Both items of the form (x + a)/b = c. - Both items provide the opportunity to demonstrate AF knowledge gap.	MKG (AF)
$\frac{n}{4} + 3 = 8$	$\frac{p}{5} + 2 = 6$	- Both items of the form x/a + b = c. - Both items provide the opportunity to demonstrate AF knowledge gap.	MKG (AF)
$5(n - 2) = 8$	$3(p - 4) = 4$	- Both items of the form a(x − b) = c. - Both items provide the opportunity to demonstrate BES misconception.	MKG (BES)

Notes. 1. Data in column 1 are from "Linear Equations: Solving Quiz B" by K. Stacey et al., 2011a (http://www.smart-quiz.edu.au/teacher). Copyright 2011 by SMART research. Reprinted with permission. 2. Data in column 4 indicate the contribution of each item towards student understanding.

The student stage of understanding was determined on Quiz C through analysis of the first eight items in Table 3.6. There were two questions for each stage of understanding, and students were required to get both correct in order to be diagnosed as demonstrating that stage. Each stage of understanding was sequentially ranked, meaning a student could not obtain a higher stage without having correctly answered the lower level stage questions (i.e., a student could not be diagnosed as Stage 3 without having correctly responded to

Stages 2 and 1 questions). This sequential ranking followed the same logic set out by Stacey et al. (2011b), as outlined in Section 3.5.1 for Quizzes A and B.

The misconception and knowledge gap categorisations were determined by reviewing students' written responses for the remaining six items. Each of these six items provided the opportunity for students to demonstrate a type of misconception or knowledge gap, and Table 3.7 summarises this for each item.

Table 3.7

Misconception and Knowledge Gap Data for Each Quiz C Item Based on Question Number

Quiz C Item	Misconception/Knowledge Gap Category
$5p - 1 = 16$	AES
$20 - 2p = 16$	RES
$2p + 7 + 3p = 6$	SE
$\frac{p+3}{7} = 2$	AF
$\frac{p}{5} + 2 = 6$	AF
$3(p - 4) = 4$	BES

Each student's written responses were analysed and categorised into the appropriate misconception or knowledge gap category using the criteria below.

Misconception (AES, RES, BES). These categories of misconceptions relate to specific ways of thinking (see Table 3.5 for a summary). Students had to either produce the specific incorrect answer demonstrating the misconception or demonstrate the misconception through the process of their working out. It was not enough for a student to respond incorrectly to one of these questions to be identified as having a misconception. Blank answers were also not considered a misconception. The specific responses required are shown in Table 3.8. The specific incorrect responses from Table 3.8 were obtained by solving the item using the misconception.

Table 3.8

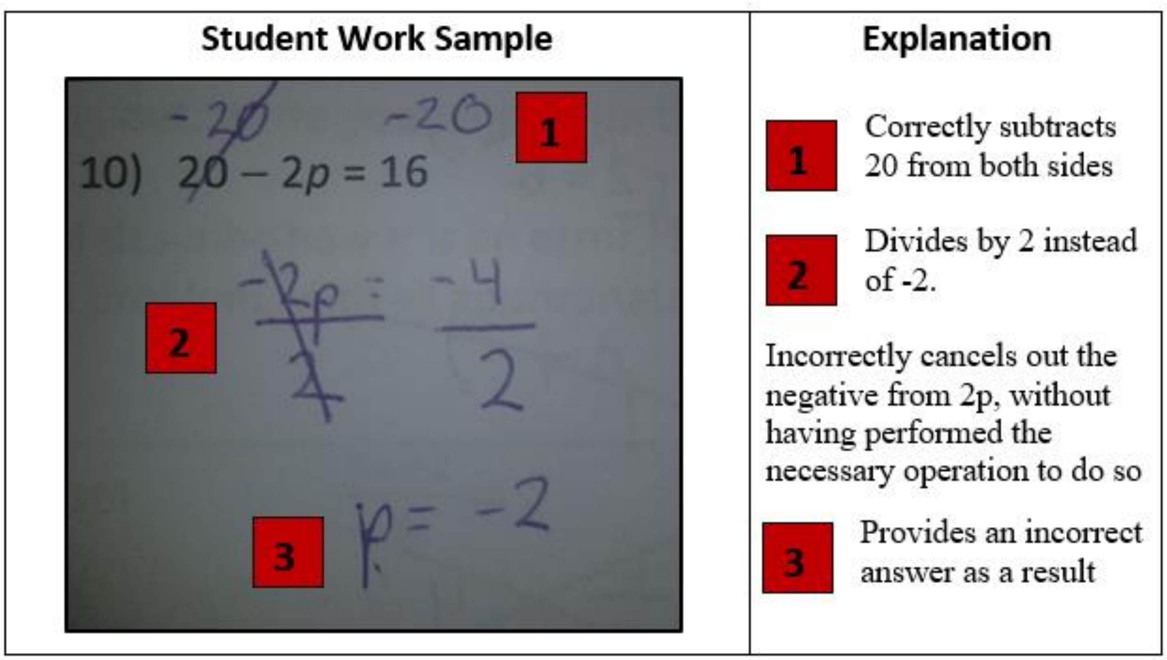
Specific Incorrect Answers Used to Identify AES, RES, and BES Misconceptions on Quiz C

Misconception Type	Item	Applied Misconception	Specific Incorrect Response
AES	$5p - 1 = 16$	Give the solution to $5p + 1 = 16$	3
RES	$20 - 2p = 16$	Give the solution to $2p - 20 = 16$	18
BES	$3(p - 4) = 4$	Give the solution to $3p - 4 = 4$	$\frac{8}{3}$

A student example (Student 5, Quiz C, Flipped Group) of an incorrect response to the RES item is shown in Figure 3.3, which shows the work of a student who has made a transposition or calculation error when solving. This incorrect answer was derived by an error in transposing the "−2"; however, they have not demonstrated the specific RES misconception in doing this.

Figure 3.3

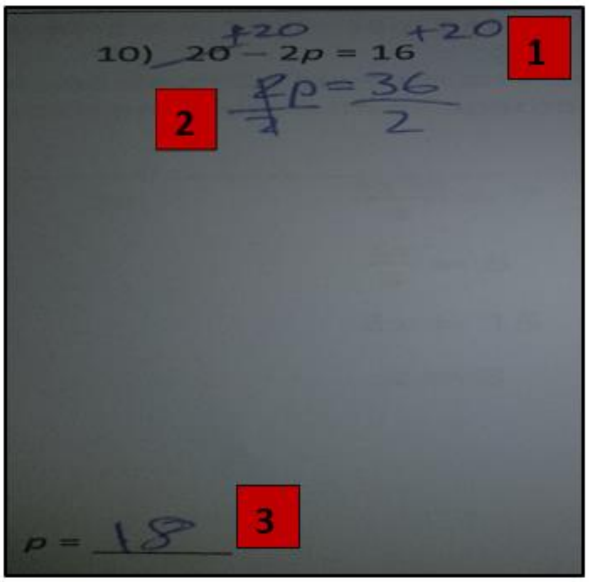
Student Example of an Incorrect Response for the RES Item on Quiz C



The student example in Figure 3.4 (Student 3, Quiz C, Flipped Group) identifies a student with the specific incorrect answer for a RES misconception, giving the solution for ax − b = c, and thus demonstrating the RES misconception. The student's process for solving further suggests that the student has an RES misconception.

Figure 3.4

Student Example of Demonstrating the RES Misconception on Quiz C

Student Work Sample	Explanation
	1 Adds 20 to each side. Instead of writing 40 on the left hand side, they have incorrectly cancelled out the +20 and 20 to give 0. 2 Writes 2p as the only remaining term on the left hand side of the equation. The student appears to be using a strategy for solving 2p – 20 = 16 (i.e. indicating they are viewing the equation as $x - a = b$) 3 Provides the specific RES answer as a result.

Misconception (SE). A written solution was needed that demonstrated simplification errors in the collection of like terms to be classified as having the SE misconception. The error could have occurred for any of the 14 items but had to be an algebraic error and not an obvious arithmetical calculation error. For example, a student who subtracts 3p from 10p to obtain 6p was considered to have made a calculation error and not have a simplification misconception. An example of an SE misconception is displayed in Figure 3.5, where the student (Student 14, Quiz C, flipped group) has been unable to simplify 2p + 3p. Students who did not write anything for Question 11 were also considered to have an SE misconception given the first step of this question could have involved adding the like terms that were on the same side. Table 3.9 presents the potential for other simplification errors on various Quiz C items.

Figure 3.5

Student Example of Demonstrating an SE Misconception on Quiz C

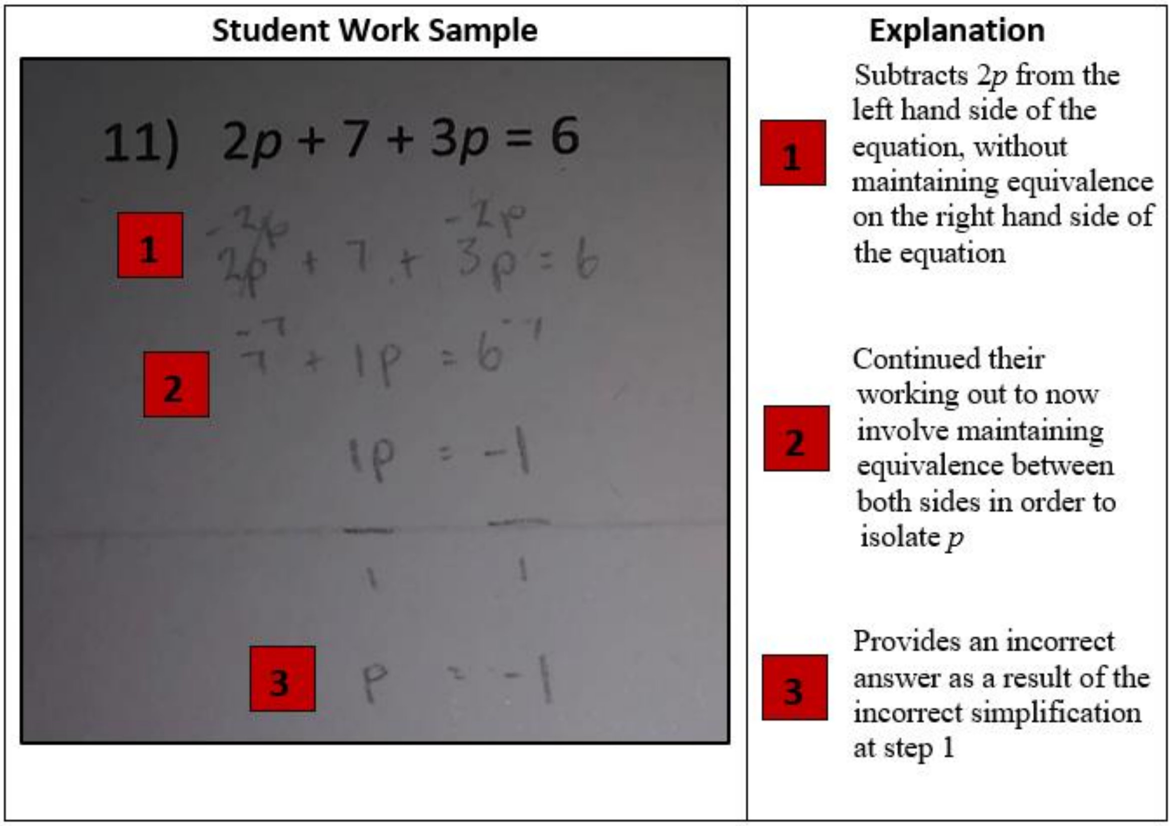


Table 3.9

Examples of Potential SE Misconceptions for Quiz C Items

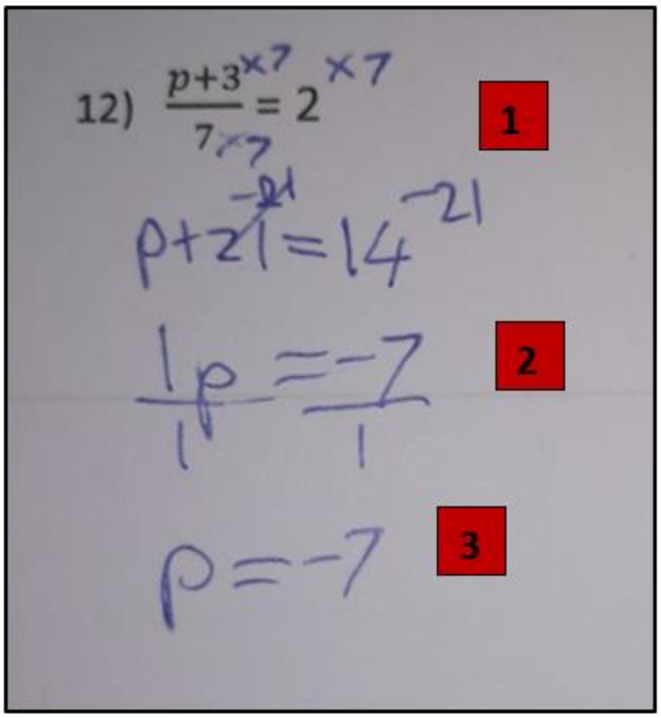
Item	Example Solution That Demonstrates SE
$9p - 13 = 4p - 6$	Subtracting $4p$ from $9p$ to result in 5 (not $5p$); any subsequent steps in the solution do not include the pronumeral
$2p + 7 + 3p = 6$	Student provided a solution where $2p + 3p$ is not written as $5p$
All	Student removes the pronumeral by incorrectly adding or subtracting it from a term (i.e., $5p - p$ is simplified to 5)

Knowledge gap (AF). A student needed to provide an incorrect answer for either Question 12 or 13. Blank responses were not considered a knowledge gap for students. Students were not classified as having an AF knowledge gap in instances where they demonstrated appropriate worked solutions, and a final incorrect answer was provided through a simple calculation error. An example of an AF knowledge gap is presented in Figure 3.6, where the student (Student 3, Quiz C, Flipped Group) has a gap in their understanding when multiplying each side by the denominator and is unable to solve an equation in the form (x + a)/b = c.

Figure 3.6

Student Example of Demonstrating the AF Knowledge Gap on Quiz C

Student Work Sample



	Explanation
1	Correctly attempts to multiply both sides by 7, however incorrectly simplifies this on the left hand side.
2	Continues with correct algebraic solving techniques, however, is now working with incorrect numbers.
3	Provides an incorrect answer as a result of incorrect simplification at step 1. Answer indicates that the student can not solve equations in the form of $(x + a)/b = c$.

3.6 Research Instrument for Student Attitude

The Mathematics and Technology Attitudes Scale (MTAS) is a survey designed to be used by students as young as 14 with widely varying scholastic abilities (Pierce et al., 2007). The MTAS was designed for use by teachers and researchers in classrooms to enable them to gauge the responses of high school students in response to trialling teaching innovations using technology. The ability of the MTAS instrument to gather students' attitudes to learning mathematics with technology made it appropriate for this study given the age of the students, the subject content being mathematics, and the integrated use of technology in the flipped classroom to learn mathematics. Furthermore, the scale was designed to be customised to context—with the last four items of the original scale amenable to modification to measure attitudes to mathematics when using specific types of technology. This facet also allowed the MTAS instrument to be customised to account for the technology use that remained constant in both classroom environments (i.e., day-to-day use of a MacBook in mathematics).

The MTAS is a 20-item survey instrument that was developed to monitor affective responses resulting from technology use that are likely to impact learning (Pierce et al., 2007). The authors minimised the number of items and used short statements, allowing the survey to be administered in 10 minutes and making it suitable for use in secondary school environments (Pierce et al., 2007).

The MTAS scale is compiled around five subscales: mathematics confidence (MC), confidence with technology (TC), attitude to learning mathematics with technology (MT), affective engagement (AE), and behavioural engagement (BE). Students self-report the extent of their agreement with each statement, which corresponds to a particular subscale for MC, TC, MT, and AE. The Likert Scale is a five-point scale, which ranges from *strongly agree* (scored as 5) to *strongly disagree* (scored as 1). A slightly different response set is used for the BE subscale, with students identifying the frequency of occurrence of different behaviours. In this response set, students respond to the five-point scale but instead respond on a sliding scale of *nearly always* (scored as 5) to *hardly ever* (scored as 1). Pierce et al. (2007) confirmed the scale's content validity and face validity and reported an "acceptable degree of internal consistency for each subscale" (p. 294), with Cronbach's alpha values for each subscale indicating a suitable level of reliability in the instrument. The MTAS scale internal consistency was tested following use in this research, with each subscale indicating an acceptable Cronbach alpha value (BE, 0.83; TC, 0.88; MC, 0.95; AE, 0.81; MT; 0.84).

In this study, the MTAS instrument was administered electronically through the Google Forms platform (see Appendix H). Minor modifications were made to the original MTAS wording to ensure the instrument was relevant to students. Section 3.6.1 provides a list of modifications and a rationale for changes from the original items.

3.6.1 MTAS Instrument: Scale Evaluation and Subscale Items

This section first provides a brief background to Pierce et al.'s (2007) evaluation of the MTAS, along with their guidelines and recommendations for how the students' Likert responses should be analysed. This section then presents each subscale item and its use or modification within this present doctoral research.

Pierce et al. (2007) trialled the MTAS instrument with 350 students from 17 classes in Years 8 to 10 from six secondary schools in Victoria, Australia. A factor analysis confirmed a five-factor structure, with four items in each factor. The scale was designed to be analysed through adding responses to the four items of each subscale, providing a maximum score of 20 in any subscale and a minimum of 4. The higher the number, the more positive the student attitude for that subscale. A score of 17 and above is considered "high", indicating a very positive attitude. A score in the range of 13 to 16 is considered "moderately high" (the term "moderate" is used in this doctoral research), and 12 or below is a "low" score, reflective of a neutral or negative attitude towards that subscale. Given that a score of 12 or below is reflective of a neutral or low attitude, anything above a 12 (i.e., moderate or high) is considered a favourable response in this doctoral research. Each of the five subscales and their subscale items are explored further in the next sections. The data from the MTAS were used to respond to RQ3.

3.6.1.1 Mathematics Confidence: Subscale and Subscale Items

Mathematics confidence, discussed through the literature review (Section 2.2.2.1), was further defined by Pierce et al., (2007) to relate to "a student's perception of their ability to attain good results and their assurance that they can handle difficulties in mathematics" (p. 290). The mathematics confidence subscale items on the MTAS allow students to self-report their level of confidence through indicating their agreement with the four statements in Table 3.10. Each subscale item provides data relating to a student's immediate reactions—rather than reflections on the past or aspirations for the future. This format allows appropriate changes in time to be mapped through monitoring changes in responses at different time points.

All the original MTAS items were retained for the mathematics confidence subscale as all were appropriate for use in this research.

Table 3.10

MTAS and Revised Subscale Items for Mathematics Confidence

Subscale Item	Original MTAS Item	Retain/ Revise	Rationale	Revised Item
MC 1	I have a mathematical mind.	Retain	Provides suitable data for student attitude in mathematics	N/A
MC 2	I can get good results in mathematics.	Retain	Provides suitable data for student attitude in mathematics	N/A
MC 3	I know I can handle difficulties in mathematics.	Retain	Provides suitable data for student attitude in mathematics	N/A
MC 4	I am confident with mathematics.	Retain	Provides suitable data for student attitude in mathematics	N/A

Note. Data in columns 1 and 2 are from "A Scale for Monitoring Students' Attitudes to Learning Mathematics With Technology" by R. Pierce et al., 2007, *Computers & Education*, *48*, p. 299. Adapted with permission.

3.6.1.2 Confidence With Technology: Subscale and Subscale Items

Confidence with technology is a subscale indicative of the assurance that students have in themselves to operate computers and the broad range of technology they would encounter inside or outside the classroom (Pierce et al., 2007).

In the original MTAS, Pierce et al. (2007) included the subscale item: "I am good at using things like VCRs, DVDs, MP3s and mobile phones" (See TC 2 in Table 3.11). This item aims to understand student confidence in using a broad range of commonly available technology, which relates to student life outside and inside the classroom. In this doctoral research, "VCR" has changed to "tablet", and "MP3s" have changed to "laptops" to reflect the evolution of technology that students in this time would be more familiar with.

Table 3.11

MTAS and Revised Subscale Items for Confidence With Technology

Subscale	Original MTAS Item	Retain/ Revise	Rationale	Revised Item
TC 1	I am good at using computers.	Retain	Students have access to computers	N/A
TC 2	I am good at using things like VCRs, DVDs, MP3s and mobile phones.	**Revise**	Wording of 'VCR' and 'MP3s' may be unfamiliar to students	I am good at using things like tablets, DVDs, laptops, and mobile phones
TC 3	I can fix a lot of computer problems.	Retain	Students have access to computers	N/A
TC 4	I can master any computer program needed for school.	Retain	Students have access to computers	N/A

Note. Data in columns 1 and 2 are from "A Scale for Monitoring Students' Attitudes to Learning Mathematics With Technology" by R. Pierce et al., 2007, *Computers & Education*, *48*, p. 299. Adapted with permission.

3.6.1.3 Attitude to Learning Mathematics With Technology: Subscale and Subscale Items

The attitude to learning mathematics with technology subscale is one that Pierce et al. (2007) suggested be edited to fit the purpose of the technology that is studied. In this doctoral research, all students (experimental and control) had access to a MacBook computer, so all items in this subscale were revised to reflect this. Table 3.12 shows how these items were revised to reflect the technology that students in both groups had available to them when learning mathematics.

Table 3.12

MTAS and Revised Subscale Items for Attitude to Learning Mathematics With Technology Subscale

Subscale	Original MTAS Item	Retain/ Revise	Rationale	Revised Item
MT 1	I like using graphics calculators for mathematics.	**Revise**	Graphics calculators are not used in this doctoral research. The online textbook (eBook) is accessed for all mathematics lessons using technology.	I like using the online eBook resource for mathematics.
MT 2	Using graphics calculators in mathematics is worth the extra effort.	**Revise**	Graphics calculators are not used in this doctoral research. Computers are used for all mathematics lessons.	Using computers in mathematics is worth the extra effort.
MT 3	Mathematics is more interesting when using graphics calculators.	**Revise**	Graphics calculators are not used in this doctoral research. Computers are used for all mathematics lessons.	Mathematics is more interesting when using computers.
MT 4	Graphics calculators help me learn mathematics better.	**Revise**	Graphics calculators are not used in this doctoral research. The online resources (embedded in the eBook) are used in mathematics lessons.	The online resources in the eBook help me learn mathematics better.

Note. Data in columns 1 and 2 are from "A Scale for Monitoring Students' Attitudes to Learning Mathematics With Technology" by R. Pierce et al., 2007, *Computers & Education, 48*, p. 300. Adapted with permission.

3.6.1.4 Behavioural Engagement: Subscale and Subscale Items

Behavioural engagement examines what students do both in and out of class in order to learn (Pierce et al., 2007). Given these attitudes were of interest and relevant for determining student attitude in this doctoral research, the original MTAS subscale items were retained in their original form (see Table 3.13).

Table 3.13

MTAS and Revised Subscale Items for Behavioural Engagement

Subscale	Original MTAS Item	Retain/ Revise	Rationale	Revised Item
BE 1	I concentrate hard in mathematics.	Retain	This item allows for attitude to be measured relating to mathematics, which was a focus of this doctoral study.	N/A
BE 2	I try to answer questions the teacher asks.	Retain	This item allows for attitude to be measured relating to mathematics, which was a focus of this doctoral study.	N/A
BE 3	If I make mistakes, I work until I have corrected them.	Retain	This item allows for attitude to be measured relating to mathematics, which was a focus of this doctoral study.	N/A
BE 4	If I can't do a problem, I keep trying different ideas.	Retain	This item allows for attitude to be measured relating to mathematics, which was a focus of this doctoral study.	N/A

Note. Data in columns 1 and 2 are from "A Scale for Monitoring Students' Attitudes to Learning Mathematics With Technology" by R. Pierce et al., 2007, *Computers & Education*, *48,* p. 299. Adapted with permission.

3.6.1.5 Affective Engagement: Subscale and Subscale Items

The affective engagement subscale items assess how students feel about mathematics. This subscale uses simple statements to determine a student's feelings towards the subject of mathematics (Pierce et al., 2007). Given these attitudes were of interest and relevant for determining student attitude in this doctoral research, the original MTAS subscale items were retained in their original form (see Table 3.14).

Table 3.14

MTAS and Revised Subscale Items for Affective Engagement

Subscale	Original MTAS Item	Retain/ Revise	Rationale	Revised Item
AE 1	I am interested to learn new things in mathematics.	Retain	This item allows for attitude to be measured relating to mathematics, which was a focus of this doctoral study.	N/A
AE 2	In mathematics you get rewards for your effort.	Retain	This item allows for attitude to be measured relating to mathematics, which was a focus of this doctoral study.	N/A
AE 3	Learning mathematics is enjoyable.	Retain	This item allows for attitude to be measured relating to mathematics, which was a focus of this doctoral study.	N/A
AE 4	I get a sense of satisfaction when I solve mathematics problems.	Retain	This item allows for attitude to be measured relating to mathematics, which was a focus of this doctoral study.	N/A

Note. Data in columns 1 and 2 are from “A Scale for Monitoring Students’ Attitudes to Learning Mathematics With Technology” by R. Pierce et al., 2007, *Computers & Education*, *48,* p. 299. Adapted with permission.

3.6.2 Flipped Classroom Open-Ended Survey

Eleven additional open-ended questions were included in the post-topic survey administered to students in the flipped classroom. These questions were designed to better understand specific elements and features of the flipped classroom that students may have utilised and either enjoyed or disliked. The open-ended nature allowed the opportunity to ensure students’ experiences could be suitably elaborated, thereby assisting to better understand students’ experiences and perspectives in the flipped classroom.

Table 3.15 displays the 11 questions and the rationale relating to each.

Table 3.15

Flipped Classroom Post-Topic Survey and Rationale

Question #	Question	Rationale
1a.	Provide some details about your experiences in being able to watch your teacher explain maths concepts through video, versus how she usually explains maths in class (when videos were not used).	Gain an understanding of the student experience in the flipped classroom with a specific reference to their previous way of learning Used to better understand the reasons behind their like, dislike, or impartial nature to a flipped approach and gain insight to the aspects they see as being important in their teacher's explanations
1b.	Considering your response above, which way of learning do you prefer, and why?	Provides an explicit opportunity for students to explain their like or dislike for a mode of learning in reference to the comments they made in the previous question
2a.	In the flipped classroom you have the opportunity to pause, rewind and review videos. Did you do this? How often did you do this?	Gain a clearer understanding of what technology-enabled flipped classroom features were most utilised by students
2b.	Provide some details on your decision why you did or did not decide to pause, rewind or review videos.	Gain insight into why students accessed (or did not access) the features available to them through the technology-enabled flipped classroom
3a.	How important was it to you that it was your teacher's voice in each video? Explain why.	Gain an understanding of whether students consider their teacher's voice vital and their reasons why/why not
3b.	Would it have made a difference to you if these videos were generic videos sourced from the internet? Explain why.	Gain further perspective on the importance of how videos are created and therefore better understand if teacher planning time could be reduced in sourcing pre-made videos from the internet
4a.	Did you watch and/or complete the flipped content on your own, or with someone else? Was there a reason you decided to watch it this way?	Gain a better understanding of students' viewing patterns and preferences when accessing lesson content
4b.	If you tried watching it in different ways, did you find one way of watching/ completing the flipped content more useful than others? Explain why.	Gain an understanding of the efficacy behind student viewing patterns and preferences from the student perspective

Question #	Question	Rationale
5a.	What was the main difference in the way you learned maths in the flipped classroom when compared to a regular maths lesson?	Gain students' insights into the differences between learning in a flipped and regular classroom
5b.	Which way of learning would you like to see more of in the future and why?	Understand student preference for future learning
6.	Provide any comments that you may have about your experience with a flipped classroom.	Students comment on aspects of the flipped classroom that could not be discussed through the previous questions.

3.7 Flipped Classroom: Design, Delivery, and Teacher Experience

This section describes the role and involvement of Kate, the teacher participant in the flipped classroom implementation. An outline of the structure and content for the flipped lessons and the design principles provided to Kate before commencing planning the flipped lessons are provided in this section. An overview of the planned similarities and differences between Kate's regular and flipped classroom groups is presented to provide a comparative reference between the flipped and nonflipped classroom. Finally, Kate's involvement in the semistructured interviews, which were used to understand the teacher experience and perspective, are discussed at the end of the section.

3.7.1 Flipped Content Creation and Delivery: Design Principles

In their synthesis of the research on the flipped classroom in K–12 mathematics education, Lo et al. (2017) proposed a set of 10 research-based design principles to help foster the transition to the flipped classroom. These principles were discussed and provided to Kate as part of her involvement in the professional learning workshops. The research-based design principles provided by Lo et al. (2017) are summarised below.

1. Manage the transition to the flipped classroom for students.
2. Manage the transition to the flipped classroom for instructors.
3. Consider presenting introductory materials and providing online support in video lectures.
4. Enable effective multimedia learning by using instructor-created short videos.
5. Use online exercises with grades to motivate students' class preparation.
6. Modify in-class teaching plans based on students' out-of-class learning performance.

7. Activate students' pre-class learning by using a structured formative assessment such as a quiz at the start of face-to-face lessons.
8. Require students to solve varied tasks and real-world problems.
9. Meet the needs of students through instructor feedback and differentiated instruction.
10. Facilitate peer-assisted learning through small-group learning activities.

While these guidelines were provided to Kate, there was no mandate from the researcher for Kate to explicitly follow these guidelines when implementing the flipped classroom.

3.7.2 Regular (Nonflipped) and Flipped Lesson Content and Structure

In this research, the initial explanations and use of examples for teaching students to solve linear equations were planned by Kate to be the same for each class. The structure relating to when and how these explanations were delivered was the only aspect planned to differ between the flipped and regular groups. The flipped (experimental) group received their initial instructional content via video format before their face-to-face lesson (pre class), and the regular (control) group received their instruction in Kate's regular pedagogical approach during their usual scheduled lesson time (in class). The comparison between pedagogy and student work expectations between the flipped and regular group is presented in Table 3.16.

Table 3.16

Categorisation of Similar and Different Aspects in the Flipped and Regular Groups

Category	Item	Group	
		Flipped	**Regular**
Pedagogical	Teacher	Same	Same
	Instructional content (examples used)	Same	Same
	Initial delivery of instructional content	Completed for homework via video tutorials (not during regular class time)	Explained by the teacher during scheduled class time
Student work requirements	Practice questions assigned to students	Same	Same
	Use of scheduled class time	Clarifying concepts Working on assigned questions	Listening to the teacher explain initial instructional content Clarifying concepts Working on assigned questions
	Typical homework routine	Watching the video tutorial for the next lesson Completing the remaining assigned questions from class	Completing the remaining assigned questions from class
	Overall work expectations	Same	Same

The content to be covered for both classes was predetermined through the Victorian Curriculum and the planning processes at School A, as previously described. This information was uploaded to School A's learning management system, with the teacher responsible delivering the content of each lesson. The lesson outline for the flipped and regular lessons in the linear equations topic is listed in Table 3.17, with each row representing a 50-minute lesson. The "Content" column within Table 3.18 makes specific reference to the online resource used by School A (Cambridge Essential Mathematics for the Victorian Curriculum, retrieved from emac.hotmaths.com.au) and outlines the content to be covered. For example, 2A refers to Chapter 2, Section A of the resource. Outside Lo et al.'s (2017) design principle guidelines and the professional learning undertaken earlier in the year (Section 3.3.2), Kate was not provided with any instruction on how many videos to create or how many explanations or examples she needed to provide within each video. The lesson notes and examples that Kate used to prepare the video tutorials for the flipped group (including the formative assessment questions) are provided in Appendix I. These were the same notes or examples and questions that were used for the regular group. Kate screencasted and recorded her explanations for the flipped group through writing on the screen using a writing tablet (Wacom Intuos) connected to the computer.

Table 3.17

Linear Equations Topic: Lesson Outlines for Flipped and Regular Groups

Lesson	Lesson Title	Content
1.	Linear Equations Pre-Test	• Previous Topic Reflection • Pre-Topic Student Attitude Survey • Linear Equations Pre-Test (Quiz A) • Set-up Transition to Flipped Classroom (for Flipped Cohort)
2.	Consolidating Algebraic Expressions (Part A)	• Consolidating Algebraic Expressions (2A)
3.	Consolidating Algebraic Expressions (Part B)	• Consolidating Algebraic Expressions (2A)
4.	Simplifying Algebraic Expressions	• Consolidating Simplification of Algebraic Expressions (2B)
5.	Simplifying Algebraic Expressions (With Brackets)	• Consolidating Simplification of Algebraic Expressions involving brackets (2C)
6.	Solving Linear Equations (Part A)	• Solving arithmetical linear equations (2D)
7.	Solving Linear Equations (Part B)	• Solving arithmetical linear equations (2D)
8.	Solving Arithmetical Linear Equations Involving Brackets	• Solving arithmetical linear equations involving brackets (2E)
9.	Solving Non-Arithmetical Linear Equations Involving Brackets (Part A)	• Solving non-arithmetical linear equations involving brackets (2E)
10.	Solving Non-Arithmetical Linear Equations Involving Brackets (Part B)	• Solving non-arithmetical linear equations involving brackets (2E)

Lesson	Lesson Title	Content
11.	Solving Linear Equations with Worded Problems (Part A)	• Solving with worded problems
12.	Solving Linear Equations with Worded Problems (Part B)	• Solving with worded problems
13.	Transposing Linear Formulae (Part A)	• Transposing linear formulae (2H)
14.	Transposing Linear Formulae (Part B)	• Transposing linear formulae (2H)
15.	Review of Content	• Review of content
16.	Linear Equations Post-Test	• Linear Equations Post-Test (Quiz B) • Post-Topic Student Attitude Survey

3.7.3 Student Access to Flipped Video Tutorials (Edpuzzle Platform)

The platform Edpuzzle (edpuzzle.com) was utilised to host video content and formative assessment opportunities for the flipped classroom students. Edpuzzle is an online platform that allows teachers to upload multimedia content and monitor student progress. Teachers have the option to embed a range of self-created questions for their students to answer while they progress through a video. The student responses to these questions can be monitored by the teacher to help determine if they understand what has been covered in the video and in turn potentially provide information on the appropriate content to cover in the following face-to-face lesson (helping towards addressing principles 4, 5, 6, 7, and 9 from Section 3.7.1). When Kate undertook the professional learning workshops at School A (Section 3.3.2), Edpuzzle was used. Given Kate's familiarity with the platform through the School A's workshops, and the ability of Edpuzzle to record student access and viewing time, the researcher asked Kate to use this platform.

The Edpuzzle platform also automatically calculates and reports the duration of time that each student has spent watching the uploaded content. Before 1 hour of viewing, the Edpuzzle system reports the total number of minutes a student has spent viewing video content. After 1 hour, Edpuzzle automatically truncates the viewing data to the hour. For example, viewing time of 1 hour and 27 minutes is truncated to 1 hour. Appendix L outlines the duration of each video Kate created for each lesson in the linear equations topic. The viewing time data were downloaded from Edpuzzle at the completion of the research (after the Quiz C time point) and is presented in Appendix K for each student.

3.7.4 Outline for Teacher Semistructured Interviews

Kate's perspectives on the flipped classroom implementation were gathered through three semistructured interviews. Semistructured interviews are a flexible technique for small-scale research (Drever, 1995). Semistructured interviews consist of predetermined questions that can have their order, wording, or structure modified based on the interviewer's perception of what seems to be most appropriate at the time (van Teijlingen, 2014). Drever (1995) defined these predetermined questions simply as the general ground intended to be covered, outlining the main questions to be asked in advanced, with the detail in structure and questioning worked out through the course of the interview. This technique provides a large degree of freedom in responses, which is useful for exploring Kate's perspective towards the flipped classroom. These interviews contributed data towards addressing RQ5 of this study. Each interview was structured through preplanned questions to gain insight into all aspects of the process, from planning and implementation to technological difficulties and perceptions of student progress and issues.

Each interview was planned a 20-minute duration at the three separate time points: before teaching the topic, halfway through teaching the topic, and at the end of the topic (see Section 3.4.2). The planned interview questions, alongside the rationale for each, are presented in Appendix L. The interviews were transcribed verbatim (Appendices M, N, and O), with the full transcript given to the teacher participant to ensure it was an accurate reflection of events. Sharing the written transcript with the teacher also provided an opportunity for her to elaborate further on points that had been discussed through the interview; any additions at this stage are noted in red on the transcript. Interview data were analysed as described in Section 3.8.3.

3.8 Method of Data Analysis

Data collected through Quizzes A, B, and C were used to determine students' understanding and MKGs and were analysed qualitatively through the process described in Section 3.8.1. The data collected through these Quizzes contributed towards answering

RQ1 and RQ2. The quantitative data collected through the MTAS survey instrument (administered pre- and post-topic) were used to determine students' attitudes when learning mathematics for both the flipped and regular groups, with this analysis described through Section 3.8.2. This analysis provided the necessary information to respond to RQ3. The experiences and perspectives of Kate and the students who participated in the flipped classroom were analysed qualitatively as described in Section 3.8.3 and 3.8.4, respectively. The experiences gathered from the students provided the necessary data for RQ4, and those gathered from the teacher provided the data for RQ5.

3.8.1 Student Understanding: Stage of Understanding, Misconceptions, and Knowledge Gap

Given that the stage of understanding and MKG data were collected in the same quiz, and all relate to student understanding, the collective term "understanding" is used to encompass all these aspects. Student understanding for Quizzes A and B were determined via the SMART test website (Section 3.5.1.1). Student understanding for Quiz C was determined by examining students' written solutions (Section 3.5.2.1).

The number of students demonstrating each stage of understanding was tallied and compared between the flipped and regular groups for Quiz A. Similarly, the number and types of MKG demonstrated were tallied and compared for each student in each group to supplement the understanding data. These understanding data provided the pre-topic understanding for each group, which was used to determine if the understanding was similar prior to intervention. This proportion of students in each stage of understanding could be further classified by a qualitative descriptor, as shown in Table 3.18.

Table 3.18

Classifications for Each Stage of Understanding for Solving Linear Equations

Stage of Understanding	Qualitative Descriptor	Descriptor
Stage 0	None	Students are unable to solve the simplest of linear equations, including those that are able to be solved through guess-and-check methods.
Stage 1	Basic	Students can solve simple linear equations that are easy to solve by guessing,
Stage 2	Developing	and can solve linear equations with more difficult answers so that a systematic method such as backtracking is required,
Stage 3	Complex	and can solve linear equations with pronumerals on both sides and only addition symbols, so that they need to be solved by "subtracting the same from both sides",
Stage 4	Complete	and can solve linear equations with pronumerals on both sides where constants and/or coefficients can be negative, so that they need to be solved by "doing the same to both sides".

Note. Adapted from "Developmental Stages and Teaching Suggestions" by K. Stacey et al., 2011a (http://www.smart-quiz.edu.au/teacher). Copyright 2011 by SMART research.

Quizzes B and C data were then analysed by comparing each individual student's stage of understanding to their previous quiz understanding. This allowed changes (i.e., increases, decreases, or retention of understanding) to be observed for students within the flipped and regular groups. For example, a student with a Stage 4 understanding in Quiz A and a Stage 3 understanding in Quiz B would be considered to have decreased one stage of understanding. This was undertaken for each student in the flipped and regular instruction groups, with the most recent previous quiz being the reference point (i.e., Quiz B compared with Quiz A, and Quiz C with Quiz B). Table 3.19 provides the contributions of each quiz towards either the pre-topic, post-topic, or delayed post-topic understanding.

Table 3.19

Quiz Requirements for Understanding Data

Initial Reference	Final Reference	Data Obtained
–	Quiz A	Pre-topic understanding
Quiz A	Quiz B	Post-topic understanding
Quiz B	Quiz C	Delayed post-topic understanding

Note. Quiz A data are only analysed when Quiz B data are present. The Quiz A data have no prior reference point and serve to demonstrate the student's pre-topic understanding and the reference point for Quiz B (post-topic understanding).

Students must have participated in both Quiz A and Quiz B assessments to have their understanding analysed. Students who were not present for the Quiz C analysis were excluded from any Quiz C analysis only; however, their Quizzes A and B were still analysed. Table 3.20 shows that students needed to be present for two consecutive tests to have their understanding data analysed.

Table 3.20

Inclusion and Exclusion Criteria for Student Understanding

Data Collected For			Data Contribute Towards
Quiz A	Quiz B	Quiz C	
✓	✓	✓	• Pre-topic understanding • Post-topic understanding • Retention of post-topic understanding
✕	✓	✓	• Retention of post-topic understanding
✓	✓	✕	• Pre-topic understanding • Post-topic understanding
✓	✕	✕	• No analysis available (understanding data excluded)
✕	✓	✕	• No analysis available (understanding data excluded)
✕	✕	✓	• No analysis available (understanding data excluded)
✕	✕	✕	• No analysis available (understanding data excluded)

Note. ✓ denotes a student contributing data for a particular data collection point. ✕ denotes a student not contributing data for a particular data collection point (typically due to student absence).

3.8.2 Student Attitude: MTAS Analysis

MTAS subscale scores were calculated for each student by adding their Likert responses within each subscale. With four items in each subscale (each ranging from 1 to 5), this allowed a maximum score of 20 and a minimum score of 4 in any subscale item. The group data for each subscale item in the flipped and regular groups were quantitatively analysed using an independent sample *t* test, with equal variances not assumed. In agreement with Rochon et al. (2012), formal preliminary testing of the data was considered unnecessary for the collected data. While the data were visually inspected for approximate normality, formal preliminary assessments of normality were not conducted given the inherent robustness of the *t* test to deviations from the normal distribution (Rasch et al., 2009). Data were analysed using IBM SPSS Statistics Software (version 25). A *p* value of less than 0.05 was required as the threshold for statistical significance. The *t* statistic, degrees of freedom, and associated *p* value are reported for each subscale in the pre- and post-topic survey results for each group (see Chapter 4). These statistical tests for significance were conducted for pre-topic survey responses to determine if there were any differences between initial group attitudes. Additionally, they were conducted for post-topic responses to determine if there were any differences in the final student attitudes after the topic (between and within groups). The results of these statistical analyses are displayed in Chapter 4.

Additionally, the attitude data were qualitatively analysed according to the classifications as set out by Pierce et al. (2007). These classification levels, described in Section 3.6.1, indicated levels of high, moderate, and low attitude responses for all subscale items for students in both groups. While the statistical tests reflected the changes to group data, the qualitative analysis allowed highlighted changes in attitude for individual students within and between groups.

The qualitative data were comparatively analysed by comparing a student's pre-survey attitude level for each subscale with their post-survey attitude level (i.e., high, moderate, and low). This comparison allowed any change in student attitude to be categorised as either increasing, decreasing, or unchanged after the topic. Furthermore, any student responding with moderate or high (i.e., score above 12) attitude was considered to have a favourable attitude in that subscale, allowing comparisons to be made in reference to favourable attitudes at each time point for each group. Patterns in the changes to individual student attitude level for each subscale were interpreted and are discussed through the discussion chapter (Chapter 6). Students must have participated in both the pre-topic survey and post-topic survey to have their attitude analysed. Students' attitudes were measured and analysed irrespective of having any stage of understanding data. Table 3.21 shows the inclusion and exclusion criteria and the data generated for analysis for attitude in this research.

Table 3.21

Inclusion and Exclusion Criteria for Student Pre- and Post-Topic Surveys

Data Collected For		Data Contribute Towards
Pre-Topic Survey	**Post-Topic Survey**	
✓	✓	• Pre-topic attitude (between groups) • Post-topic attitude (between groups)
✕	✓	• No analysis available (survey data excluded)
✓	✕	• No analysis available (survey data excluded)
✕	✕	• No analysis available (survey data excluded)

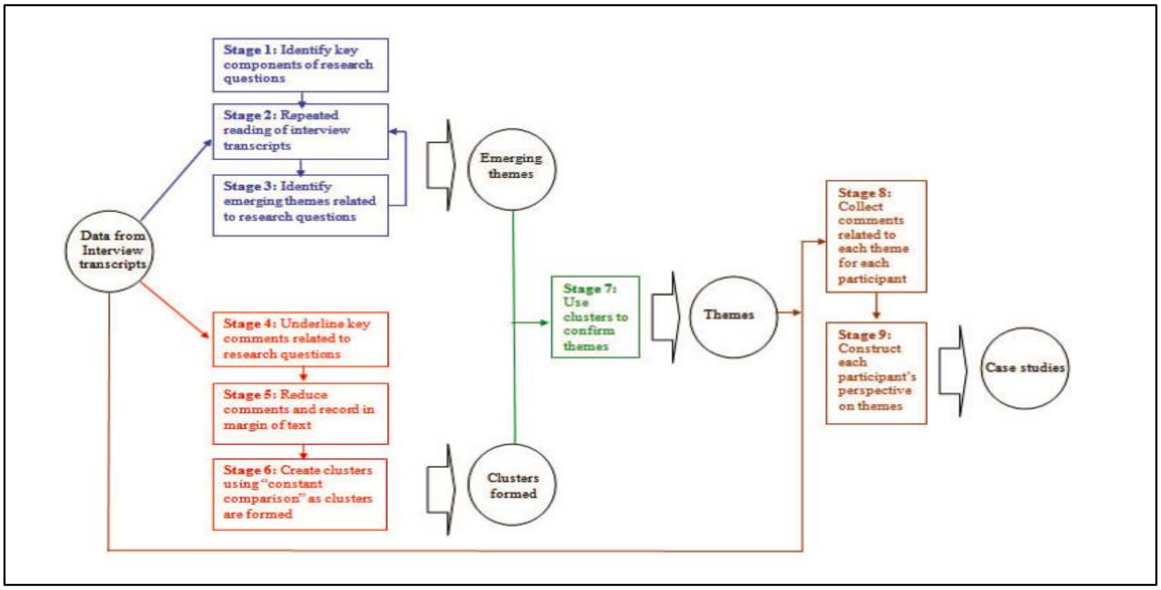
Note. ✓ denotes a student contributing data for a particular data collection point. ✕ denotes a student not contributing data for a particular data collection point (typically due to absence).

3.8.3 Teacher Experience and Perspective: Semistructured Teacher Interview Analysis

The three teacher semistructured interviews were transcribed verbatim following each interview. These transcripts were analysed qualitatively for clusters and themes in relation to answering RQ5. This study was guided by the nine-stage approach as outlined by Ball (2011) for the analysis of interview transcripts (see Figure 3.7).

Figure 3.7

Nine-Stage Process for Analysis of Interview Transcripts to Determine Themes



Note. From "Analysing Interview Data for Clusters and Themes" by L. Ball, 2011, in J. Clark, B. Kissane, J. Mousley, T. Spencer, & S. Thornton (Eds.), *Mathematics: Traditions and (New) Practices: Proceedings of the 34th Annual Conference of the Mathematics Education Research Group of Australasia and the Association of Mathematics Teachers* (p. 91). Adelaide: AAMT and MERGA.

In determining themes, it was necessary to continually revisit the data in an attempt to seek out themes that, when taken together, provided the best explanation of "what's going on" in an inquiry (Srivastava & Hopwood, 2009). The transcripts from each time point were therefore continually revisited to establish an initial set of emerging themes (Stages 1 to 3). Ball (2011) explained that the two terms "emerging themes" and "themes" are the products of two different aspects of transcript analysis, with themes only confirmed after Stage 6. Kate would often revisit items that she had discussed earlier in the same interview, and so it was necessary to group these similar ideas into "clusters" (Stages 4 to 6). This was achieved through highlighting comments and paraphrasing them in the margin of the transcript, with like-minded paraphrased comments forming the basis of a single cluster. An example of the outcomes of Stages 4 and 5 are depicted in Figure 3.8.

Figure 3.8

Verbatim Teacher Interview Excerpt and Paraphrased Comments That Illustrate the Product of Stages 4 and 5

Stage 4: Highlighted interview comments relevant to research question	Stage 5: Paraphrased Comments
Umm…Yes, I must say that going into the flipped class I am less stressed with the fact that I'm not time constrained with, you know, oh we need to get through this, this and this. Umm, so I know, sort of I know what is going to happen in the flipped class… umm, and how much time we are going to have to work on it. Whereas with the other class, because I want to allow them time to work in class it's always sort of a struggle, and then you have the behavioural issues because they've had enough of hearing you…. so going into a flipped class…yes, its surprisingly more relaxing… than going into a non-flipped.. with the…you know, with the time stress.	Teacher feels less stressed when entering the flipped classroom. Teacher has a clearer expectation of what will happen in each flipped class and how the lesson will play out. Teacher finds struggles with time and subsequent behaviour in the regular class. Teacher finds more stress in the face-to-face component regular classroom and finds the face-to-face flipped class more relaxing.

Any paraphrased comment that was intended (whether inferred or explicitly stated) to convey a similar focus to another paraphrased comment would belong to the same cluster. Figure 3.9 demonstrates how clusters were formed grouped across multiple interviews, using some of the paraphrased comments from the previous example in Figure 3.8. The products of Stage 6 were considered concerning the emerging themes generated from Stages 1 to 3 and, through consultation and collaboration with research supervisors, final themes were identified and confirmed (Stage 7). The themes relating to the teacher experience in a flipped classroom are presented in Chapter 5, along with the clusters that formed each.

Figure 3.9

Example of a Teacher Cluster With Associated Paraphrased Comments Across Multiple Semistructured Teacher Interviews

Cluster	Paraphrased Comments (Interview 1)	Paraphrased Comments (Interview 2)	Paraphrased Comments (Interview 3)
Teacher feels less stress in the face-to-face flipped classroom when compared with the face-to-face regular classroom	N/A	Teacher feels less stressed when entering the flipped classroom. Teacher finds more stress in the face-to-face component of the regular classroom and finds the face-to-face flipped classroom more relaxing. Teacher has a clearer expectation of what will happen in each flipped class and how the lesson will play out. Teacher finds struggles with time (regular classroom).	Less "energy" needed on the teacher's behalf to run the face-to-face classes during the unit. Teacher was continually less stressed going into the flipped class, with a constant expectation of how the lesson would progress.

3.8.4 Flipped Classroom: Student Experience and Perspective

To address RQ4, the student responses to the 11 open-ended questions from the post-topic survey were analysed utilising a similar format described in Section 3.8.3, with one slight change. Given that student responses were relatively brief, paraphrasing them was an unnecessary step. Therefore, when considering the analysis presented in Section 3.8.3, instead of paraphrasing comments to form clusters, the students' verbatim comments were placed directly into a cluster. An example of one cluster and the associated student comments are shown in Figure 3.10, with all clusters and student comments presented in Appendix P.

Figure 3.10

Example of a Student Cluster With Verbatim Comments

Cluster	Student Comments
Ability to pause a video enables time to process new skills or concepts	• . . . especially during the exercises so it gave me more time to process the information given to me [S12-3]. • Sometimes I was confused as to what I was writing and pausing allowed me to stop and think [S7-2]. • So that I fully understood how to do the equation step by step [S22-4]. • I often paused because I couldn't keep up with the video which was annoying [S6-2]. • . . . I also paused so i [*sic*] can get a good view on how to do it [S23-3]. • I paused the videos due to the video going really quickly . . . [S15]. • The difference was that you had time to process, write and evaluate everything you've done in the video, in comparison to when you're in maths class and you're being fed the answers [S13-3].

Note. Numbers in parenthesis indicate the unique student and the number of comments they had contributed to separate clusters up to that point; that is, [S13-3] means Student 13 is making their third contribution to a cluster.

3.9 Limitations and External Validity of Design

This section acknowledges the theoretical limitations of the presented research, considering several factors that contribute to the external validity of the research design. External validity refers to the ability of a study to generalise its outcomes to different contexts (Walser, 2014). Trochim (2020) described this as the degree to which conclusions in a study can hold true for other persons, in other places, at other times. This study's quasi-experimental design has several assumptions and limitations that contribute to its external validity. The factors that limit the generalisability of findings are explored further through the discussion (Chapter 6) and conclusion (Chapter 7); however, they are briefly introduced here and mainly pertain to the following:

Time of intervention. This study took place over a 7-week period of the school year within one topic of linear equations. This provided adequate insight for student understanding and attitude over this duration. However, it does not allow for generalisability over longer periods of time (or within other topics of mathematics).

Hawthorne effect. This threat is based on the premise that subjects who know that they are participating in an experiment can tend to alter their usual behaviours in response (Bracht & Glass, 1968). This can then confound the intervention's impact, causing results that would not otherwise have been observed if it were not an "experiment". This threat is valid for any type of experimental design whether it is a quasi or true experiment. However, the advantage to the quasi-experimental design is that the experimental arrangement may not appear as obvious to students given this quasi design was conducted in the students' usual class environment.

Participant numbers. This study was conducted in one school environment and focused on one teacher of two Year 9 mathematics classes. More participants would enhance the capacity for generalisation.

Planning time, resources, and school support. School A provided 1.5 hours per fortnight of planning time for teachers to explore the concept of flipped learning and create content using the provided resources and expertise. This set-up may not be possible at other schools and therefore could impact the overall generalisability of the results obtained through this research.

Chapter 4.

Student Attitude and Understanding: Results From Student Surveys and Quizzes

This chapter presents the results that relate to student attitude to learning mathematics and student understanding of solving linear equations. Student attitude, as reported through the MTAS survey, is presented and analysed for each of the five subscales from both pre- and post-topic time points for the flipped and regular groups (Section 4.1). Student understanding of solving linear equations, including MKGs, are then presented through the analysis of Quizzes A, B, and C in Section 4.2. The analysis and further discussion of these results are presented in Chapter 6.

4.1 Student Attitude: MTAS Survey Results

Student attitude was measured through the MTAS instrument over five subscales: behavioural engagement, confidence with technology, affective engagement, mathematics confidence, and attitude to learning mathematics with technology. Student pre- and post-topic survey scores were quantitatively analysed using an independent sample *t* test, with equal variances not assumed, as described in Section 3.8.2. A *p* value of less than 0.05 was required as the threshold for results to be considered statistically significant.

The descriptive statistics and statistical analysis results are presented in Table 4.1. The data for the pre-topic survey responses indicated no significant differences between the flipped and regular classroom groups for any subscale item, confirming both the flipped and regular groups were statistically similar for all five subscale attitude measures before commencing the linear equations topic.

Table 4.1

Pre-Topic Descriptive Statistics and Statistical Analysis for the Flipped and Regular Groups

	Group (Pre-Topic Results)								
Subscale	**Flipped**			**Regular**					
	M	***SD***	***n***	***M***	***SD***	***n***	***t***	***df***	***p***
MC	14.18	3.57	22	13.10	4.43	21	-0.884	38	.382
TC	15.45	2.74	22	14.19	3.01	21	-1.438	40	.158
MT	14.23	2.39	22	13.48	4.01	21	-0.742	32	.463
BE	15.95	3.55	22	15.67	3.02	21	-0.287	40	.776
AE	14.73	2.47	22	14.19	3.86	21	-0.541	34	.592

Note. MC = mathematics confidence, TC = confidence with technology, MT = attitude to learning mathematics with technology, BE = behavioural engagement, AE = affective engagement. Data were analysed using an independent sample *t* test, with equal variances not assumed. All *p* values were greater than 0.05 and hence not statistically significant.

The data for the post-topic survey responses again demonstrated no significant differences between the flipped and regular groups for any subscale item, indicating that both the flipped and regular groups were statistically similar for all five subscale attitude measures at the end of the linear equations topic. The descriptive statistics, along with the statistical analysis results, are presented in Table 4.2.

Table 4.2

Post-Topic Descriptive Statistics and Statistical Analysis for the Flipped and Regular Groups

Subscale	Group (Post-Topic Results)								
	Flipped			Regular					
	M	***SD***	***n***	***M***	***SD***	***n***	***t***	***df***	***p***
MC	13.91	3.81	22	12.86	5.28	21	-0.746	36	.460
TC	14.73	2.78	22	13.86	2.87	21	-1.009	41	.319
MT	15.09	2.54	22	13.95	3.32	21	-1.257	37	.216
BE	15.68	3.10	22	15.38	3.76	21	-0.286	39	.777
AE	14.50	2.99	22	13.86	4.03	21	-0.592	37	.557

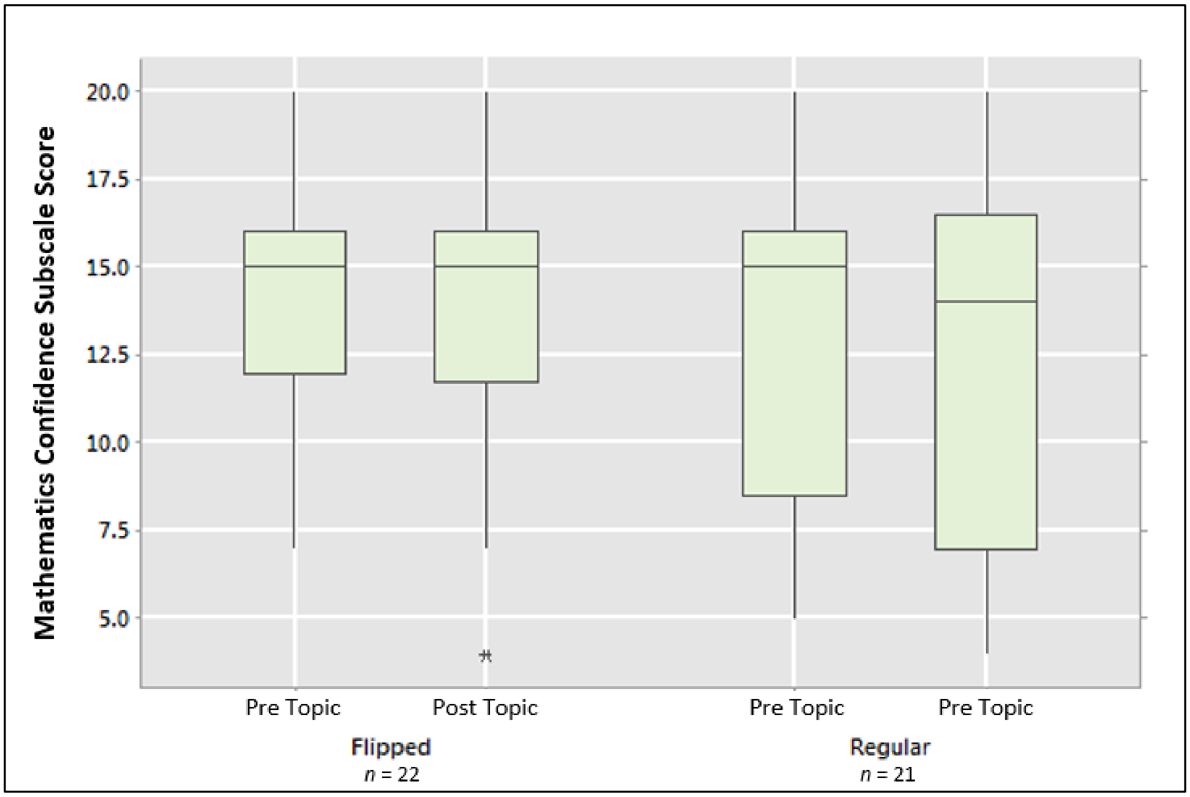
Note. MC = mathematics confidence, TC = confidence with technology, MT = attitude to learning mathematics with technology, BE = behavioural engagement, AE = affective engagement. Data were analysed using an independent sample *t* test, with equal variances not assumed. All *p* values were greater than 0.05 and hence not statistically significant.

4.1.1 Mathematics Confidence Subscale

Mathematics confidence, as outlined in Section 3.6.1, relates to a student's perception of their ability to attain good results in mathematics and their assurance that they are able to handle difficult situations in mathematics. Figure 4.1 shows the median for both groups to indicate a moderate-level attitude (i.e., score between 13 and 16; see Section 3.6.1) before the linear equations topic. Although a marginal decrease in the post-topic median was observed for the regular group, the median for both the flipped and regular groups continued to indicate a moderate-level attitude after the topic.

Figure 4.1

Students' Mathematics Confidence Pre and Post Topic: Flipped and Regular Groups



The pre- and post-topic matched data for each student in the flipped and regular groups for the MC subscale are presented in Figures 4.2 and 4.3, respectively. The number of students reporting a favourable attitude (i.e., moderate or high) in the flipped group remained the same post topic (16 students). The regular group had an increase in the number of students reporting a favourable attitude from 12 students pre topic to 14 students post topic.

Figure 4.2

Students' Attitude: Mathematics Confidence Pre and Post Topic for the Flipped Group

		Post-Topic Attitude			
		Low	Moderate	High	Number of students (pre topic)
Pre-Topic Attitude	Low	4	2	0	6
	Moderate	2	9	1	12
	High	0	2	2	4
	Number of students (post topic)	6	13	3	22

KEY

- Decreased two levels from pre topic
- Decreased one level from pre topic
- No change from pre topic
- Increased one level from pre topic
- Increased two levels from pre topic

Figure 4.3

Student Attitude: Mathematics Confidence Pre and Post Topic for the Regular Group

		Post-Topic Attitude			
		Low	Moderate	High	Number of students (pre topic)
Pre-Topic Attitude	Low	7	2	0	9
	Moderate	0	6	2	8
	High	0	1	3	4
	Number of students (post topic)	7	9	5	21

KEY

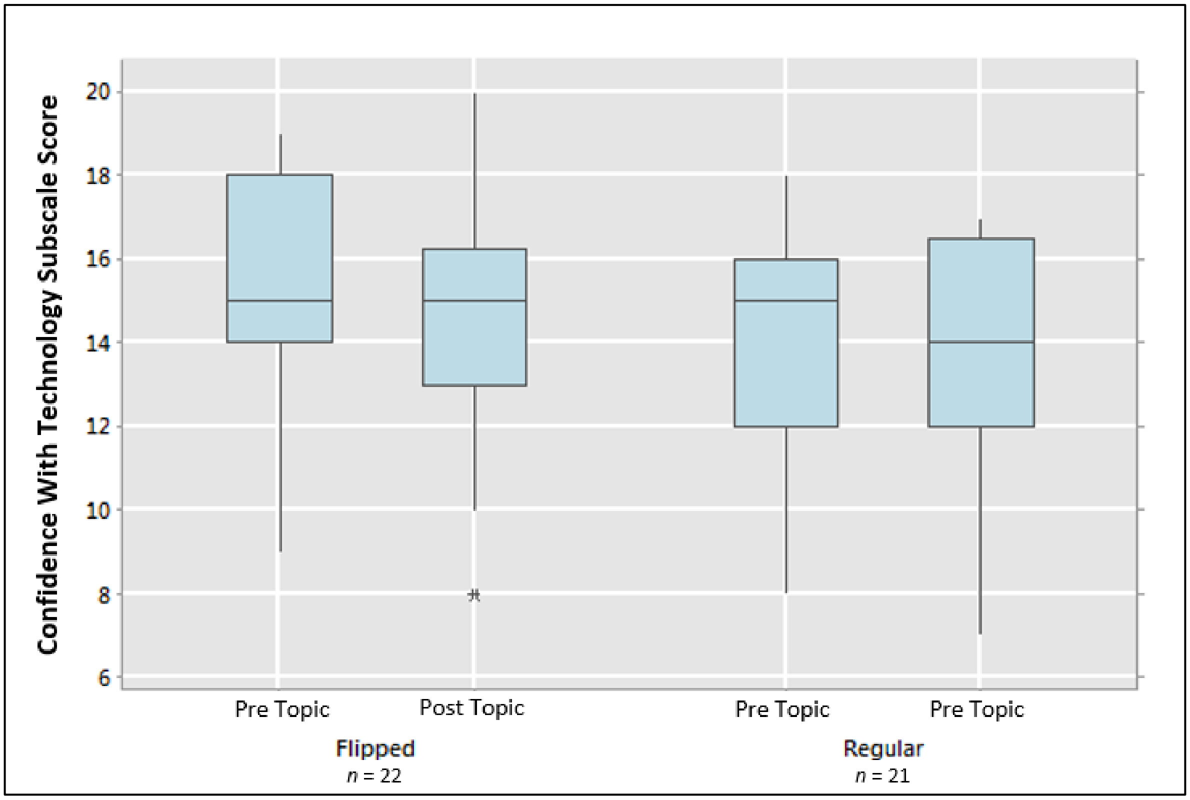
- Decreased two levels from pre topic
- Decreased one level from pre topic
- No change from pre topic
- Increased one level from pre topic
- Increased two levels from pre topic

4.1.2 Confidence with Technology Subscale

As discussed in Section 3.6.1, confidence with technology is a subscale indicative of the assurance that students have in themselves to use a range of commonly available technology, both in and outside the classroom. Figure 4.4 shows the median for both the flipped and regular groups to indicate a moderate-level attitude before commencing the topic. Following the completion of the topic, despite a slight decrease in the median of the regular group, the median for both the flipped and regular groups continued to demonstrate a moderate-level attitude towards confidence with technology.

Figure 4.4

Students' Confidence With Technology Pre and Post Topic: Flipped and Regular Groups



The pre- and post-topic matched data for each student in the flipped and regular groups for the TC subscale are presented in Figures 4.5 and 4.6, respectively. The flipped group decreased in the number of students with a favourable attitude response from 20 students pre topic to 18 students post topic. A similar decrease was observed for the regular group, with two fewer students reporting a favourable attitude after the topic (17 students pre topic and 15 students post topic).

Figure 4.5

Student Attitude: Confidence With Technology Pre and Post Topic for the Flipped Group

		Post-Topic Attitude			
		Low	Moderate	High	Number of students (pre topic)
Pre-Topic Attitude	Low	1	1	0	2
	Moderate	3	7	0	10
	High	0	5	5	10
	Total number of students (post topic)	4	13	5	22

KEY

Decreased two levels from pre topic; Decreased one level from pre topic; No change from pre topic; Increased one level from pre topic; Increased two levels from pre topic

Figure 4.6

Student Attitude: Confidence With Technology Pre and Post Topic for the Regular Group

		Post-Topic Attitude			
		Low	Moderate	High	Number of students (pre topic)
Pre-Topic Attitude	Low	4	0	0	4
	Moderate	2	8	3	13
	High	0	2	2	4
	Total number of students (post topic)	6	10	5	21

KEY

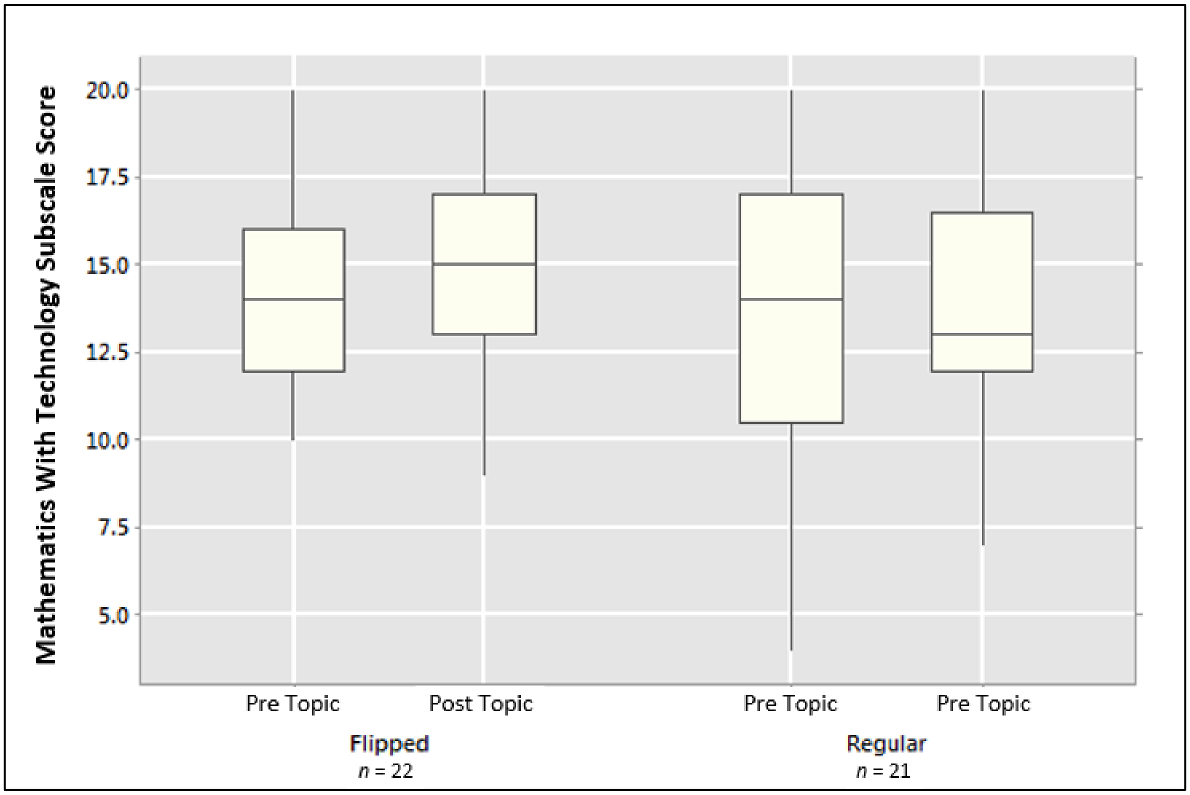
Decreased two levels from pre topic; Decreased one level from pre topic; No change from pre topic; Increased one level from pre topic; Increased two levels from pre topic

4.1.3 Attitude to Learning Mathematics With Technology Subscale

Mathematics with technology is a measure of student attitude to learning mathematics with the use of technology (see Section 3.6.1). Figure 4.7 shows the median for both groups to indicate a moderate-level attitude before the linear equations topic. Despite increases to the median attitude of the flipped group, and a similar magnitude decrease for the regular group, the median for both groups continued to indicate a moderate-level attitude for learning mathematics with technology after the topic.

Figure 4.7

Students' Attitude to Learning Mathematics With Technology Pre and Post Topic: Flipped and Regular Groups



The pre- and post-topic matched data for each student in the flipped and regular groups for the MT subscale are presented in Figures 4.8 and 4.9, respectively. The number of students reporting a favourable attitude increased by five students in the flipped group between pre- and post-topic surveys. The number of students reporting a favourable attitude in the regular group remained the same between pre- and post-topic survey measures.

Figure 4.8

Student Attitude: Learning Mathematics With Technology Pre and Post Topic for the Flipped Group

		Post-Topic Attitude			
		Low	Moderate	High	Number of students (pre topic)
Pre-Topic Attitude	Low	1	2	3	6
	Moderate	0	13	1	14
	High	0	0	2	2
	Total number of students (post topic)	1	15	6	22

KEY

- Decreased two levels from pre topic
- Decreased one level from pre topic
- No change from pre topic
- Increased one level from pre topic
- Increased two levels from pre topic

Figure 4.9

Student Attitude: Learning Mathematics With Technology Pre and Post Topic for the Regular Group

		Post-Topic Attitude			
		Low	Moderate	High	Number of students (pre topic)
Pre-Topic Attitude	Low	6	2	0	8
	Moderate	2	5	1	8
	High	0	1	4	5
	Total number of students (post topic)	8	8	5	21

KEY

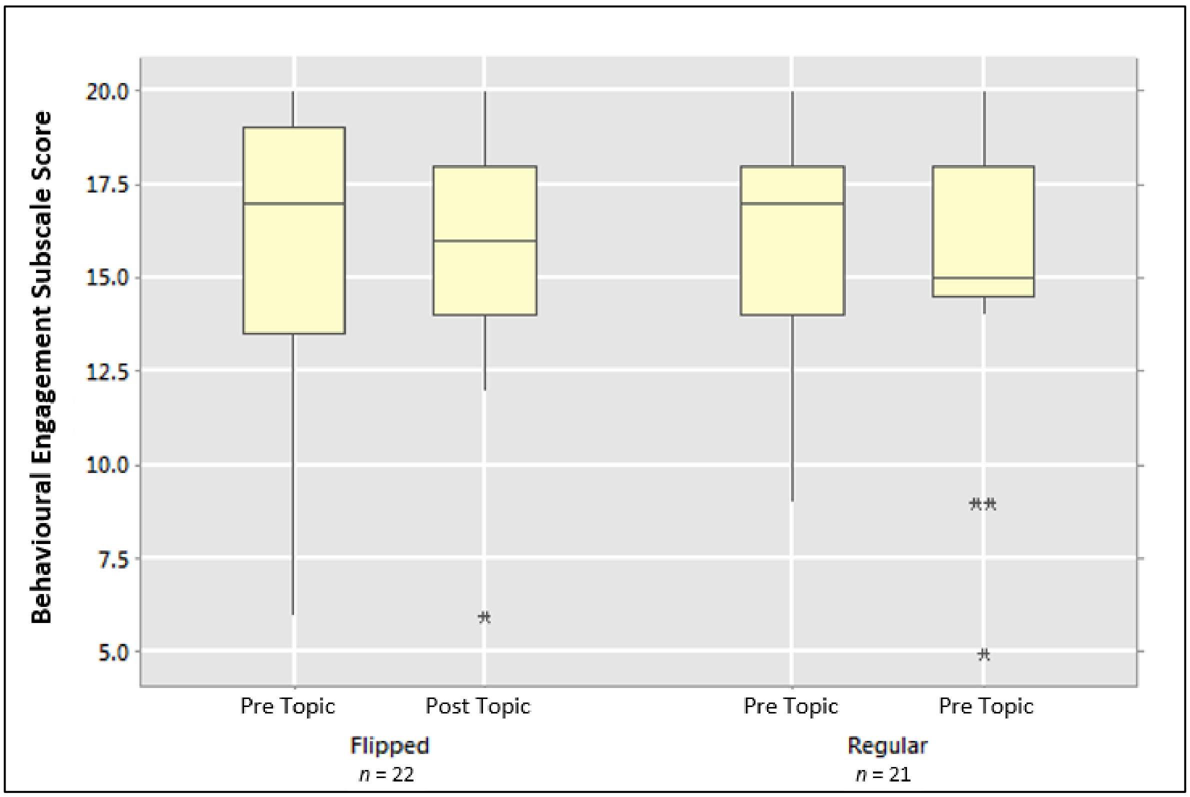
- Decreased two levels from pre topic
- Decreased one level from pre topic
- No change from pre topic
- Increased one level from pre topic
- Increased two levels from pre topic

4.1.4 Behavioural Engagement Subscale

Behavioural engagement reflects students' behaviours and dispositions both in and out of class as they learn mathematics. The median for both the flipped and regular groups indicated a moderate-level attitude before the linear equations topic. The median attitude for each group decreased between pre- and post-topic measures; however, both groups continued to demonstrate a median indicative of a moderate-level attitude after the topic, as shown in Figure 4.10.

Figure 4.10

Students' Behavioural Engagement Pre and Post Topic: Flipped and Regular Groups



The pre- and post-topic matched data for each student in the flipped and regular groups for the behavioural engagement subscale are presented in Figures 4.11 and 4.12, respectively. The flipped group increased the number of students with favourable responses from 17 students pre topic to 20 students post topic, whereas the number of students with a favourable response remained the same before and after the topic in the regular group (18 students).

Figure 4.11

Student Attitude: Behavioural Engagement Pre and Post Topic for the Flipped Group

		Post-Topic Attitude			
		Low	Moderate	High	Number of students (pre topic)
Pre-Topic Attitude	Low	2	3	0	5
	Moderate	0	3	0	3
	High	0	5	9	14
	Total number of students (post topic)	2	11	9	22

KEY

Decreased two levels from pre topic; Decreased one level from pre topic; No change from pre topic; Increased one level from pre topic; Increased two levels from pre topic

Figure 4.12

Student Attitude: Behavioural Engagement Pre and Post Topic for the Regular Group

		Post-Topic Attitude			
		Low	Moderate	High	Number of students (pre topic)
Pre-Topic Attitude	Low	3	0	0	3
	Moderate	0	6	1	7
	High	0	2	9	11
	Total number of students (post topic)	3	8	10	21

KEY

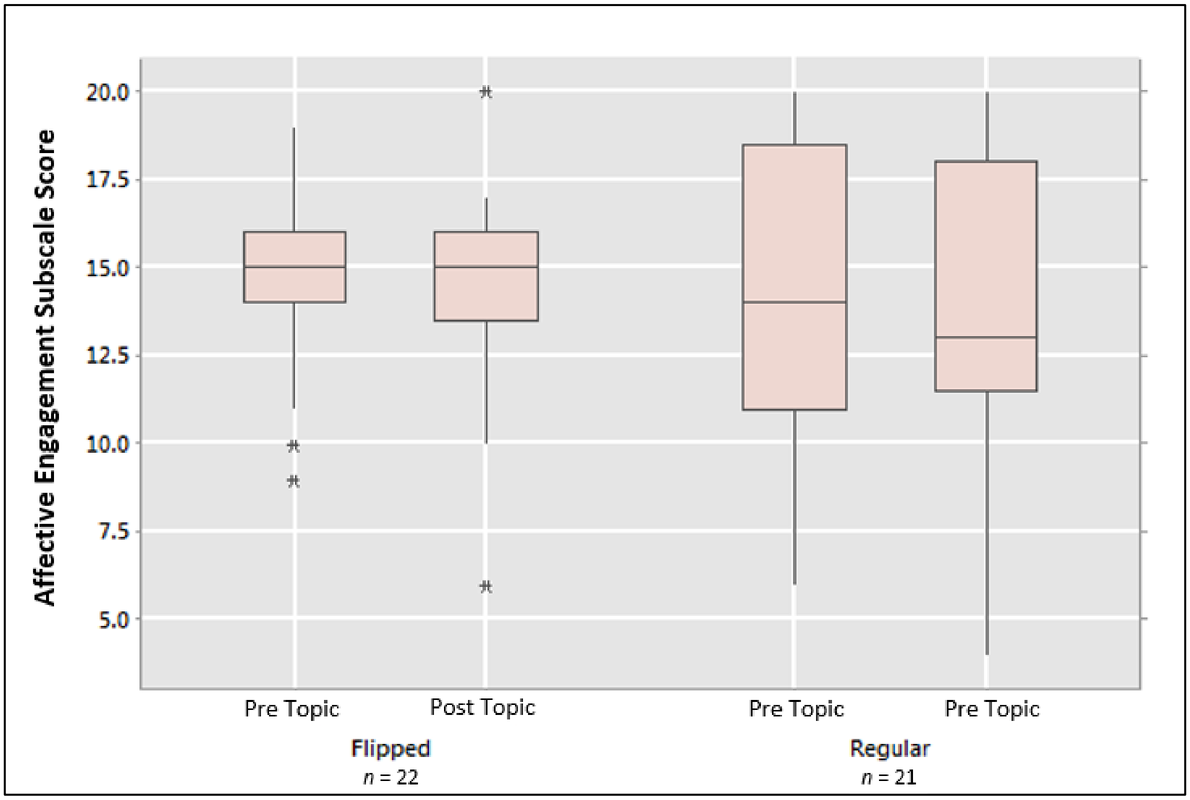
Decreased two levels from pre topic; Decreased one level from pre topic; No change from pre topic; Increased one level from pre topic; Increased two levels from pre topic

4.1.5 Affective Engagement Subscale

As indicated by Figure 4.13, the median for both the flipped and regular groups of students indicated a moderate-level attitude before the linear equations topic. While the median for the regular group decreased marginally in the post-survey measure, both groups continued to indicate a moderate-level attitude for affective engagement.

Figure 4.13

Students' Affective Engagement Pre and Post Topic: Flipped and Regular Groups



The pre- and post-topic matched data for each student in the flipped and regular groups for the affective engagement subscale are presented in Figures 4.14 and 4.15, respectively. The number of students reporting a favourable attitude decreased by one student from pre to post topic in both the flipped and regular groups.

Figure 4.14

Student Attitude: Affective Engagement Pre and Post Topic for the Flipped Group

		Post-Topic Attitude			
		Low	Moderate	High	Number of students (pre topic)
Pre-Topic Attitude	Low	4	0	0	4
	Moderate	1	11	3	15
	High	0	2	1	3
	Total number of students (post topic)	5	13	4	22

KEY

Decreased two levels from pre topic; Decreased one level from pre topic; No change from pre topic; Increased one level from pre topic; Increased two levels from pre topic

Figure 4.15

Student Attitude: Affective Engagement Pre and Post Topic for the Regular Group

		Post-Topic Attitude			
		Low	Moderate	High	Number of students (pre topic)
Pre-Topic Attitude	Low	5	2	0	7
	Moderate	3	3	2	8
	High	0	1	5	6
	Total number of students (post topic)	8	6	7	21

KEY

Decreased two levels from pre topic; Decreased one level from pre topic; No change from pre topic; Increased one level from pre topic; Increased two levels from pre topic

4.2 Student Understanding of Solving Linear Equations

Student understanding of solving linear equations, as measured through two online SMART tests (Quizzes A and B) and one pen-and-paper written test (Quiz C), is presented in this section for both the flipped and regular groups. The student stage of understanding data and the MKG data are presented for each group, providing information on student understanding pre and post topic. To highlight areas of change, the stage of understanding from each quiz was compared to the quiz that preceded it, as described in Section 3.8.1.

4.2.1 Flipped Group: Stage of Understanding Results for Quizzes A and B

Figure 4.16 presents the pre- and post-topic data for each student in the flipped group, using each student's diagnosed stage of understanding from Quiz A (pre topic) and B (post topic).

Figure 4.16

Student Understanding: Matched Student Pre- and Post-Topic Stage of Understanding Results from Quizzes A and B for the Flipped Group

		Stage of Understanding Quiz B					Number of Students (Quiz A)
		0	1	2	3	4	
Stage of Understanding Quiz A	0	1	0	0	0	0	1
	1	0	1	0	6	0	7
	2	0	0	0	5	3	8
	3	0	1	0	2	3	6
	4	0	0	0	0	0	0
Number of students (Quiz B)		1	2	0	13	6	22

KEY

Decreased three stages from Quiz A; Decreased two stages from Quiz A; Decreased one stage from Quiz A; No change in stage from Quiz A; Increased one stage from Quiz A; Increased two stages from Quiz A; Increased three stages from Quiz A; Increased four stages from Quiz A

Figure 4.16 shows that of the 22 students, 17 increased in their stage of understanding from Quiz A to Quiz B (77% of students). Sixteen students were diagnosed at Stage 2 or below before commencing the topic, which decreased to three students post topic (two of whom were diagnosed at this stage pre topic). Nineteen students in the sample were diagnosed with a Stage 3 or 4 understanding post topic.

4.2.2 Flipped Group: Misconceptions and Knowledge Gap Results for Quizzes A and B

Student MKG data, as identified through Quizzes A and B in the flipped group, are presented in Table 4.3. The results from the pre-topic test (Quiz A) showed a large proportion of students (18 students, equivalent to 82% of students in the flipped group sample) to exhibit a simplification error (SE) misconception. The addition equation solution (AES) was the next prevalent misconception, with 10 students (45% of students in this sample) diagnosed with this misconception. Bracketless equation solution (BES) and reverse equation solution (RES) were the next most common misconceptions with seven (32%) and five (23%) students demonstrating these misconceptions, respectively. No student from the flipped group was diagnosed with the algebraic fraction (AF) knowledge gap in Quiz A. Overall, 40 instances of misconceptions were diagnosed through pre-testing, with all but two students demonstrating at least one type of misconception.

The results from the post-topic test data (Quiz B) showed a large reduction in the number of students diagnosed with an SE misconception, with seven students exhibiting this misconception (32% of students in this sample), a reduction of over half that seen in pre-testing (61% decrease; 11 fewer students). The second highest misconception at pre-testing, AES had only one student retaining that misconception from Quiz A. However, an additional student was diagnosed with this misconception during Quiz B, leaving a total of two students with this misconception after Quiz B. There were no incidences of students diagnosed with BES or RES misconceptions on Quiz B, despite having students with these misconceptions on Quiz A. Seven students demonstrated an AF knowledge gap on the post-test. Nine instances of misconceptions (SE and AES) and seven instances of knowledge gap (AF) were diagnosed in Quiz B. This represents 31 fewer instances in misconceptions and seven more instances of knowledge gap when compared to pre-test results. Twelve students in the flipped group demonstrated at least one type of misconception or knowledge gap, a reduction of 40% (eight fewer students) when compared with Quiz A.

Table 4.3

Misconception and Knowledge Gap Data From Quizzes A and B for the Flipped Group

	Quiz A Misconception/Knowledge Gap							Quiz B Misconception/Knowledge Gap					
Student	SE	AES	BES	RES	AF	Student's Total		SE	AES	BES	RES	AF	Student's Total
1	SE					1							0
2	SE	AES				2							0
3	SE	AES	BES	RES		4		SE					1
4						0							0
5	SE					1						AF	1
6	SE		BES	RES		3		SE	AES			AF	3
7	SE	AES				2		SE	AES				2
8	SE		BES			2		SE					1
9	SE		BES			2						AF	1
10	SE	AES				2							0
11		AES				1							0
12						0							0
13	SE	AES	BES			3						AF	1
14	SE					1		SE					1
15	SE					1		SE					1
16		AES				1							0
17	SE	AES		RES		3						AF	1
18	SE	AES				2		SE				AF	2
19	SE	AES	BES	RES		4						AF	1
20	SE					1							0
21	SE					1							0
22	SE		BES	RES		3							0
Number of misconceptions and knowledge gaps	18	10	7	5	0	40		7	2	0	0	7	16

Note. SE = simplification error, AES = addition equation solution, BES = bracketless equation solution, RES = reverse equation solution, AF = algebraic fraction.

4.2.3 Regular Group: Stage of Understanding Results for Quizzes A and B

Figure 4.17 shows that of the 23 students, 16 (70%) increased in their diagnosed stage of understanding from Quiz A to Quiz B. Twenty-one students were diagnosed with Stage 2 or below before the topic, with this number decreasing to six students after Quiz B.

Seventeen students were diagnosed with Stage 3 or Stage 4 at the time of Quiz B in the regular group.

Figure 4.17

Student Understanding: Matched Student Pre- and Post-Topic Stage of Understanding Results From Quizzes A and B for the Regular Group

		Stage of Understanding Quiz B					Number of Students (Quiz A)
		0	1	2	3	4	
Stage of Understanding Quiz A	0	1	0	0	3	2	6
	1	2	3	0	5	0	10
	2	0	0	0	3	2	5
	3	0	0	0	1	1	2
	4	0	0	0	0	0	0
Number of students (Quiz B)		3	3	0	12	5	23

KEY

- Decreased three stages from Quiz A
- Decreased two stages from Quiz A
- Decreased one stage from Quiz A
- No change in stage from Quiz A
- Increased one stage from Quiz A
- Increased two stages from Quiz A
- Increased three stages from Quiz A
- Increased four stages from Quiz A

4.2.4 Regular Group: Misconceptions and Knowledge Gap Results for Quizzes A and B

Student MKG data as diagnosed through Quizzes A and B in the regular group are presented in Table 4.4. The pre-topic test (Quiz A) demonstrated a large proportion of students (21 students, equivalent to 91% of students in the regular group sample) to exhibit an SE misconception. The AES was the next highest misconception, with eight students (35% of students in this sample) demonstrating it. BES and AF (a knowledge gap) were the next most prevalent MKGs, with two students diagnosed with these (9% of students in this sample). One student was diagnosed with RES through pre-testing. Overall, 32 instances of misconceptions and two instances of knowledge gap were diagnosed through pre-testing, with all 23 students in the sample diagnosed with at least one type of misconception or knowledge gap.

The post-test data (Quiz B) demonstrated a large reduction in the number of students demonstrating an SE misconception, with nine students exhibiting this misconception (12 fewer students when compared with Quiz A). The second highest misconception at pre-testing, AES reduced from eight students at Quiz A to two students at Quiz B. This resulted from one student retaining the misconception and another being diagnosed with the misconception in Quiz B. Both students who were diagnosed with the BES misconception no longer displayed it on Quiz B; however, two additional students were diagnosed with the misconception, resulting in no overall change to the number of students with a BES misconception. The one student who demonstrated an RES misconception on the pre-test no longer did so on the post-test. The number of students demonstrating an AF knowledge gap increased by three more students; this was in addition to the same two students from pre-testing retaining their knowledge gap, resulting in a total of five students with an AF knowledge gap. A total of 13 misconceptions and five knowledge gaps were identified on the post-test. In comparison to pre-test results, there were 19 fewer instances of misconceptions and three more instances of the AF knowledge gap. Fourteen students (nine fewer) in the sample demonstrated at least one type of misconception or knowledge gap when compared with Quiz A.

Table 4.4

Misconception and Knowledge Gap Data From Quiz A and B for the Regular Group

	Quiz A Misconception/Knowledge Gap						Quiz B Misconception/Knowledge Gap					
Student	SE	AES	BES	RES	AF	Student's Total	SE	AES	BES	RES	AF	Student's Total
1	SE					1	SE				AF	2
2	SE	AES	BES			3	SE					1
3	SE					1	SE					1
4	SE	AES				2	SE					1
5	SE					1						0
6	SE					1						0
7	SE					1	SE					1
8	SE	AES				2						0
9	SE					1		AES	BES			2
10	SE	AES		RES		3		AES			AF	2
11	SE					1						0
12		AES	BES			2						0
13	SE					1						0
14	SE					1						0
15	SE					1	SE					1
16	SE					1	SE					1
17		AES			AF	2					AF	1
18	SE					1	SE					1
19	SE	AES				2					AF	1
20	SE					1						0
21	SE	AES			AF	3					AF	1
22	SE					1	SE		BES			2
23	SE					1						0
Number of misconceptions and knowledge gaps	21	8	2	1	2	34	9	2	2	0	5	18

Note. SE = simplification error, AES = addition equation solution, BES = bracketless equation solution, RES = reverse equation solution, AF = algebraic fraction.

4.2.5 Flipped Group: Stage of Understanding Results for Quiz C (Delayed Test)

Figure 4.18 presents the stage of understanding for Quiz B (post topic) and Quiz C (delayed test) for each student in the flipped group. The Quiz C data were collected approximately 3 weeks following Quiz B. The total number of students in this sample decreased by two compared to the post-topic understanding data due to student absence at the time of Quiz C (refer to Section 3.8.1 for inclusion/exclusion criteria).

Figure 4.18

Student Understanding: Matched Student Pre- and Post-Topic Stage of Understanding Results From Quizzes B and C for the Flipped Group

		Stage of Understanding Quiz C					Number of Students (Quiz B)
		0	1	2	3	4	
Stage of Understanding Quiz B	0	1	0	0	0	0	1
	1	1	0	0	1	0	2
	2	0	0	0	0	0	0
	3	0	0	1	6	4	11
	4	0	0	0	1	5	6
Number of students (Quiz C)		2	0	1	8	9	20

KEY

- Decreased three stages from Quiz B
- Decreased two stages from Quiz B
- Decreased one stage from Quiz B
- No change in stage from Quiz B
- Increased one stage from Quiz B
- Increased two stages from Quiz B
- Increased three stages from Quiz B
- Increased four stages from Quiz B

Figure 4.18 shows that of the 20 students, five improved their stage of understanding between Quiz B and Quiz C. Eleven students retained the same Stage 3 or 4 understanding they were diagnosed with 3 weeks earlier. Three students decreased one stage after the 3-week period. Of the 20 students, 17 (85%) in this sample were diagnosed with a Stage 3 or 4 understanding in Quiz C, equalling the same proportion of students with this stage of understanding in Quiz B.

4.2.6 Flipped Group: Misconceptions and Knowledge Gap Results for Quiz C (Delayed Test)

The Quiz C MKG data for the flipped group are presented in Table 4.5. Four students were diagnosed with an SE misconception on Quiz C, which was three fewer students than compared with Quiz B. A reduction in the diagnosis of the AES misconception was observed, with only one student diagnosed with the AES misconception at Quiz C. The two students who had demonstrated the AES misconception during Quiz B no longer demonstrated this on Quiz C; however, an additional student was diagnosed with the misconception, leaving the total at one. The total number of students with the BES misconception remained at zero for Quiz C. While no student was diagnosed with the RES misconception in Quiz B, one student was diagnosed with this in Quiz C. The AF knowledge gap continued to be the most prevalent of errors, increasing from seven students with the diagnosis at Quiz B to eight students at Quiz C. This resulted from five students retaining the knowledge gap and an additional three demonstrating it, having not done so at the time of Quiz B.

Overall, Quiz C showed three fewer instances of diagnosed misconceptions (six total) but one more instance of the AF knowledge gap (eight total) when compared to Quiz B. Ten students in the sample demonstrated at least one type of misconception or knowledge gap in Quiz C, which is two fewer students when compared with Quiz B.

Table 4.5

Misconception and Knowledge Gap Data From Quizzes B and C for the Flipped Group

	Quiz B Misconception/Knowledge Gap						Quiz C Misconception/Knowledge Gap					
Student	SE	AES	BES	RES	AF	Student's Total	SE	AES	BES	RES	AF	Student's Total
1						0						0
2						0						0
3	SE					1				RES	AF	2
4						0	**ABSENT**					
5					AF	1					AF	1
6	SE	AES			AF	3					AF	1
7	SE	AES				2						0
8	SE					1	SE					1
9					AF	1					AF	1
10						0						0
11						0	**ABSENT**					
12						0						0
13					AF	1					AF	1
14	SE					1	SE					1
15	SE					1	SE				AF	2
16						0						0
17					AF	1						0
18	SE				AF	2	SE	AES			AF	3
19					AF	1						0
20						0						0
21						0					AF	1
22						0						0
Number of misconceptions and knowledge gaps	7	2	0	0	7	16	4	1	0	1	8	14

Note. SE = simplification error, AES = addition equation solution, BES = bracketless equation solution, RES = reverse equation solution, AF = algebraic fraction.

4.2.7 Regular Group: Stage of Understanding Results for Quiz C (Delayed Test)

Figure 4.19 presents the stage of understanding results for Quiz B (post topic) and Quiz C (delayed test) for each student in the regular group. The Quiz C data were collected approximately 3 weeks following Quiz B. The total number of students in this sample decreased by one compared to the post-topic understanding data due to student absence at the time of Quiz C (refer to Section 3.8.1 for inclusion/exclusion criteria).

Figure 4.19

Student Understanding: Matched Student Pre- and Post-Topic Stage of Understanding Results From Quizzes B and C for the Regular Group

		Stage of Understanding Quiz C					Number of Students (Quiz B)
		0	1	2	3	4	
Stage of Understanding Quiz B	0	2	0	0	1	0	3
	1	2	0	1	0	0	3
	2	0	0	0	0	0	0
	3	1	1	2	2	6	12
	4	0	0	0	2	2	4
Number of students (Quiz C)		5	1	3	5	8	22

KEY

Decreased three stages from Quiz B; Decreased two stages from Quiz B; Decreased one stage from Quiz B; No change in stage from Quiz B; Increased one stage from Quiz B; Increased two stages from Quiz B; Increased three stages from Quiz B; Increased four stages from Quiz B

Figure 4.19 shows that of the 22 students, eight improved their stage of understanding between Quiz B and Quiz C (including one student demonstrating three stages of progression). Four students retained the same Stage 3 or 4 understanding they were diagnosed with 3 weeks earlier. Eight students decreased in their stage of understanding (including one student demonstrating three stages of regression) at Quiz C. Overall, of the 22 students, 13 (59%) in this sample were diagnosed with a Stage 3 or 4 understanding in Quiz C, which was three students fewer than at Quiz B.

4.2.8 Regular Group: Misconceptions and Knowledge Gap Results for Quiz C (Delayed Test)

The MKG data from Quiz C are presented in Table 4.6 for the regular group.

There were eight students diagnosed with the SE misconception on Quiz C, which was one fewer student when compared to Quiz B. The two students who were diagnosed with the AES misconception during Quiz B were no longer diagnosed with this at Quiz C. However, an additional student developed the misconception, leaving one student with this misconception. The two students diagnosed with a BES misconception after Quiz B no longer had this diagnosis after Quiz C, resulting in no student with the BES misconception in the regular group. The number of students diagnosed with the RES misconception increased from zero (Quiz B) to two students at Quiz C. The number of students with an AF knowledge gap doubled between Quizzes B and C, with 10 students diagnosed with the AF knowledge gap at Quiz C.

Overall, Quiz C showed two fewer instances of diagnosed misconceptions (11 instances) and five more instances of the AF knowledge gap (10 students) when compared to Quiz B. Fourteen students in the sample demonstrated at least one type of misconception or knowledge gap, which is the same number of students as Quiz B.

Table 4.6

Misconception and Knowledge Gap Data From Quizzes B and C for the Regular Group

	Quiz B Misconception/Knowledge Gap							Quiz C Misconception/Knowledge Gap					
Student	SE	AES	BES	RES	AF	Student's Total		SE	AES	BES	RES	AF	Student's Total
1	SE				AF	2		SE				AF	2
2	SE					1		SE	AES			AF	3
3	SE					1		SE				AF	2
4	SE					1							0
5						0						AF	1
6						0					RES	AF	2
7	SE					1		SE				AF	2
8						0							0
9		AES	BES			2		SE					1
10		AES			AF	2					RES	AF	2
11						0						AF	1
12						0							0
13						0		**ABSENT**					
14						0							0
15	SE					1		SE					1
16	SE					1		SE					1
17					AF	1							0
18	SE					1		SE					1
19					AF	1						AF	1
20						0							0
21					AF	1						AF	1
22	SE		BES			2							0
23						0							0
Number of misconceptions and knowledge gaps	9	2	2	0	5	18		8	1	0	2	10	21

Note. SE = simplification error, AES = addition equation solution, BES = bracketless equation solution, RES = reverse equation solution, AF = algebraic fraction.

This chapter presented the data relating to students' attitudes from the MTAS survey (Section 4.1) and students' understanding through stage of understanding and MKG data (Section 4.2) that were collected from Quizzes A, B, and C. The next chapter presents the data relating to the students' and teacher's perspectives relating to the flipped classroom.

Chapter 5.

Perceptions About the Flipped Classroom: Qualitative Responses From Students and Teacher

This chapter presents the results relating to student and teacher experiences and perspectives of the flipped classroom. These results provide the data to address RQ4 and RQ5 of this doctoral research. Section 5.1 outlines the themes and clusters that arose through students' open-ended responses to the post-topic survey in the flipped group. The teacher's perspectives, as detailed through the themes and clusters from the three semistructured interviews, are presented through Section 5.2.

5.1 Post-Topic Survey Data: Analysis of Students' Experiences and Perspectives of the Flipped Classroom

This section analyses the data obtained from the open-ended portion of the post-topic survey for the flipped group students. Data are grouped and analysed as described through Section 3.8.4 of Chapter 3. In total, 19 clusters were identified across the student responses, and these were categorised into five overarching themes, as presented in Table 5.1. The themes and clusters, along with representative verbatim student comments, are provided in the ensuing subsections.

Table 5.1

Student Themes and Clusters for the Flipped Classroom

Theme	Cluster	Students
Student Control of Learning	S1.1 Video tutorials allow students to control the pace of their learning.	13
	S1.2 Students re-watch video tutorials as needed.	6
	S1.3 Students are able to learn independently of the needs of others.	3
Concentration and Focus	S2.1 Watching video tutorials alone assists concentration.	8
	S2.2 Easy to lose focus when watching video tutorials at home.	2
Student Understanding	S3.1 Ability to pause a video enables time to process new skills or concepts.	7
	S3.2 Flipped classroom supports ease in student learning.	7
	S3.3 Reviewing video tutorials improves understanding.	6
	S3.4 Flipped learning is an effective way to learn mathematics.	4
	S3.5 Embedded formative assessment in video tutorials assists student learning.	3
	S3.6 In-class examples enable more in-depth explanation of content.	3
	S3.7 Regular classroom (nonflipped) supports student learning.	2
Features of a Flipped Classroom	S4.1 Ability to pause a video allows time to copy examples/notes.	9
	S4.2 Inability to get immediate clarification from the teacher when difficulties in video explanations are encountered is problematic for students.	6
	S4.3 Watching video tutorials at home enables more time in class for teacher assistance.	4
	S4.4 Ability to seek clarification from the teacher in class after difficulties in video explanations are encountered is utilised by students.	3
Student Preferences Regarding Flipped Videos	S5.1 Preference for their teacher to have created the flipped video tutorials.	9
	S5.2 Students opt to watch video tutorials alone to suit their needs.	6
	S5.3 No preference for their teacher to have created the flipped video tutorials.	3

Note. “Students” is a tally of the number of students who made comments relating to a specific cluster. Some students may have made more than one comment relating to the same cluster; however, this is not recorded or represented as part of the tally (i.e., a student can only be counted once in the tally for a cluster). No tally is provided for the themes; some students may have commented on more than one cluster within a theme.

5.1.1 Student Theme 1: Student Control of Learning

The *Student Control of Learning* theme refers to how students were able to control their own learning through participation in a flipped classroom. Control of learning relates to students' ability to control the pace or speed that content was covered and the opportunity to review content as they required. It highlights students' ability to work at a pace independent of the learning needs or requests of others, which may have otherwise consumed their time in the regular classroom. This theme includes three clusters as shown in Table 5.1a.

Table 5.1a

Student Theme 1: Student Control of Learning

Theme	Cluster		Students
Student Control of Learning	S1.1	Video tutorials allow students to control the pace of their learning.	13
	S1.2	Students re-watch video tutorials as needed.	6
	S1.3	Students are able to learn independently of the needs of others	3

Note. 'Students' is a tally of the number of students who made comments relating to a specific cluster. Some students may have made more than one comment relating to the same cluster; however, this is not recorded or represented as part of the tally (i.e., a student can only be counted once in the tally for a cluster).

Cluster S1.1, *Video tutorials allow students to control the pace of their learning,* relates to students' ability to control the pace of learning through participation in the flipped classroom. Students in this cluster commented on being able to take more time to write notes and understand what had been explained by the teacher through pausing or rewinding video tutorials when required. The following two student comments are reflective of the responses in this cluster:

> I like doing maths through the videos because I can go at my own pace and pause the video whenever I need it and it gives me more time to understand the concepts. (S12-1)

> I can take as much time as I want to write things down but in class I have to write things quickly or I have to wait till the teacher finishes writing down things before I can copy it. (S16-1)

Both comments highlight the ability to pace the video tutorial to suit their needs. While the reasons were different for these students (i.e., pausing for understanding and taking extra time to copy notes), both indicated the video tutorials had allowed them a useful way to control the pace that content was presented.

Cluster S1.2, *Students re-watch video tutorials as needed,* was the second-largest cluster of this theme (six students). Comments in this cluster related to students being able to continually review concepts as many times as required whenever they wanted. Examples of student comments included the following:

> Its [*sic*] better to watch my teacher explain concepts through a video because i [*sic*] can watch videos over and over until i [*sic*] get it. (S23-1)

> The videos I believe is better for me as I can re-watch a video as many times I need to understand the subject. (S3-2)

Both comments reinforce the need for students to revisit explanatory content as required to gain an understanding of what had been covered through the tutorial.

Cluster S1.3, *Students are able to learn independently of the needs of others,* related to the ability of the flipped classroom to support students to work independently, without having to wait for the teacher to cater to the needs of others. For example, "I don't have to wait for others or others don't need to wait for me" (S3-3) suggests that students were able to learn independently of the needs of other students, and the rate at which this student learned would not impact the rate of learning for the rest of the class.

Through the comments reported by students, these three clusters showed that in the flipped classroom, students could control their learning. They reported the ability to control the speed at which they watched a tutorial (S1.1), the number of times to review the tutorial (S1.2), and the capacity to do this independently of the needs of other students' decisions regarding their pace (S1.3).

5.1.2 Student Theme 2: Concentration and Focus

Students in the flipped classroom were required to watch video tutorials to learn the concepts for each lesson in the linear equations topic. The *Concentration and Focus* theme captures the comments made by students that referenced their ability to concentrate and focus on content explanations through learning through video tutorials. This theme includes two clusters (Table 5.1b).

Table 5.1b

Student Theme 2: Concentration and Focus

Theme	Cluster	Students
Concentration and Focus	S2.1 Watching video tutorials alone assists concentration.	8
	S2.2 Easy to lose focus when watching video tutorials at home.	2

Note. "Students" is a tally of the number of students who made comments relating to a specific cluster. Some students may have made more than one comment relating to the same cluster; however, this is not recorded or represented as part of the tally (i.e., a student can only be counted once in the tally for a cluster).

Cluster S2.1, *Watching video tutorials alone assists concentration,* contains the comments from students who reported that they decided to watch the video tutorials alone as this allowed them to concentrate on the content covered. For example, the student comment "I watched the video on my own so that I was able to concentrate and focus" (S2-8) demonstrates that watching the video tutorials assisted with concentration and focus.

Cluster S2.2, *Easy to lose focus when watching video tutorials at home,* provides a countered view to S2.1 from some students. The student comments in this cluster highlighted the difficulty for students to concentrate on content resulting from the need to watch and learn through video tutorials at home. Both the students who formed this cluster referenced the fact that their home environment made it more difficult than learning through the classroom:

> I probably prefer learning in a classroom, as it is easier to lose focus when at home. I think it takes longer for me to watch the videos and take the notes at home, therefore taking more time out of my personal life. Usually it does not

> take me so long to do math homework because the exercises usually set do not take as long to do. (S1-5)

> Id [*sic*] prefer the standard method only because i [*sic*] get distracted more at home. (S4-3)

Through the comments reported by students in this theme, these three clusters showed the flipped classroom to be both a positive and negative influence on student concentration and focus. While the majority of students in this theme found it easier to concentrate on videos by themselves (eight students, S2.1), others indicated difficulty in being able to maintain focus on the videos in their home environment (two students, S2.2).

5.1.3 Student Theme 3: Student Understanding

The theme *Student Understanding* refers to the specific aspects of the flipped classroom that either assisted (S3.1, S3.2, S3.3, S3.4, S3.5) or hindered (S3.6, S3.7) student understanding when learning to solve linear equations. The seven clusters in this theme (Table 5.1c) provide detail from the students' perspectives as to how and why their understanding was influenced through the flipped classroom, with these explored further below.

Table 5.1c

Student Theme 3: Student Understanding

Theme	Cluster	Students
Student Understanding	S3.1 Ability to pause a video enables time to process new skills or concepts.	7
	S3.2 Flipped classroom supports ease in student learning.	7
	S3.3 Reviewing video tutorials improves understanding.	6
	S3.4 Flipped learning is an effective way to learn mathematics.	4
	S3.5 Embedded formative assessment in video tutorials assists student learning.	3
	S3.6 In-class examples enable more in-depth explanation of content.	3
	S3.7 Regular classroom (nonflipped) supports student learning.	2

Note. "Students" is a tally of the number of students who made comments relating to a specific cluster. Some students may have made more than one comment relating to the same cluster; however, this is not recorded or represented as part of the tally (i.e., a student can only be counted once in the tally for a cluster).

Cluster S3.1, *Ability to pause a video enables time to process new skills or concepts,* highlights that the feature of pausing the video provided students with the necessary time to understand what was being covered. Student 13 found that this was the largest difference between a flipped and regular classroom through commenting, "The difference was that you had time to process, write and evaluate everything you've done in the video, in comparison to when you're in maths class and you're being fed the answers" (S13-3).

The comment of providing additional time to process and understand information was common for students in this cluster, with Student 7 stating, "Sometimes I was confused as to what I was writing and pausing allowed me to stop and think" (S7-2). These two representative comments highlight that the feature of pausing assisted in providing students with the necessary time to understand and process what had been said in the video.

Cluster S3.2, *Flipped classroom supports ease in student learning,* was formed through comments that referenced students' perceptions that a flipped classroom made it easier for them to learn and understand content. Some comments such as "I would like to do flipped learning again because it did make it easier for me to learn" (S18-6) were broad in their statement of how it made learning easier. However, others were specific as to how it made it easier “because writing notes down was a problem to me in class and being able to do it at home is much easier for me” (S16-6).

Cluster S3.3, *Reviewing video tutorials improves understanding*, reflects comments made by students about their ability to review the video tutorials, which in turn contributed to their perception of an improved understanding of the content. Students’ comments that referred to reviewing videos, such as “If i [*sic*] needed clarification for something, I just went back and rewatched until it made sense” (S9-3) and “Being able to acquire a better understanding of what I am trying to learn by rewinding” (S14-3) suggests that videos were being re-watched by students to improve their understanding.

Cluster S3.4, *Flipped learning is an effective way to learn mathematics,* was formed by comments such as “The flipped classroom is better as it teaches the same content and in shorter periods and at your own speed” (S3-6) and “I believe it is a more effective way of teaching” (S11-5). These comments highlight students’ positive perspectives on the effectiveness of the flipped classroom.

Cluster S3.5, *Embedded formative assessment in video tutorials assists student learning*, highlights the importance of quiz questions for students. Comments such as “The quizes [*sic*] made you to make sure that you were paying attention and not just taking notes” (S2-3) were reflective of this cluster and communicated the importance of including formative assessment in video tutorials.

Cluster S3.6, *In-class examples enable more in-depth explanation of content,* is reflective of student perceptions such as “I prefer the normal math classes as if needed more examples and more of an explanation can be given” (S2-5). This cluster suggests that some students preferred the regular classroom due to the inability of the flipped classroom to assist in opportunities to deepen their understanding of content by providing further or additional in-depth explanations.

Cluster S3.7, *Regular classroom (nonflipped) supports student learning,* was formed by some students’ perceptions that the regular classroom better supported student understanding when compared to the flipped classroom. Student 8’s comment to “keep it normal because if I get tuck [*sic*] the teacher can help me in class and push me to work harder" (S8-2) suggests that students found the physical presence of the teacher to be more supportive to their learning.

Through the comments reported by students in this theme, these clusters showed that student understanding was generally positively influenced by student participation in the flipped classroom. This perspective was supported by students who reported that pausing (S3.1) and reviewing (S3.3) made it easier (S3.2) and more effective (S3.4) for them to understand the content in the flipped classroom. However, this was not unanimous comment for all students, with concerns raised about the depth of content that could be covered in a flipped video (S3.6) and perceived disparity in support between the regular and flipped classroom (S3.7).

5.1.4 Student Theme 4: Features of a Flipped Classroom

The *Features of a Flipped Classroom* theme refers to student perspectives about the use and interaction with various features that are incumbent in participation in the flipped classroom. This theme contained both positive (S4.1, S4.3, S4.4) and negative (S4.2) perceptions. The four clusters in this theme (Table 5.1d) are explored below.

Table 5.1d

Student Theme 4: Features of a Flipped Classroom

Theme	Cluster		Students
Features of a Flipped Classroom	S4.1	Ability to pause a video allows time to copy examples/ notes.	9
	S4.2	Inability to get immediate clarification from the teacher when difficulties in video explanations are encountered is problematic for students.	6
	S4.3	Watching video tutorials at home enables more time in class for teacher assistance.	4
	S4.4	Ability to seek clarification from the teacher in class after difficulties in video explanations are encountered is utilised by students.	3

Note. "Students" is a tally of the number of students who made comments relating to a specific cluster. Some students may have made more than one comment relating to the same cluster; however, this is not recorded or represented as part of the tally (i.e., a student can only be counted once in the tally for a cluster).

Cluster S4.1, *Ability to pause a video allows time to copy examples/notes,* is exemplified by Student 20's comment that they "decided to pause videos so I can copy down notes" (S20-4). This suggests that the pause feature was useful for providing time for the transfer of written explanations into their notebook. This practice is further highlighted by Student 16, who shared, "I paused the videos so that I could copy the things already on the video before I play it or I wait till the teacher is done writing things down and I pause it and copy everything into my book" (S16-3).

Cluster S4.2, *Inability to get immediate clarification from the teacher when difficulties in video explanations are encountered is problematic for students,* highlights a negative perception of the flipped classroom. The facet of having to listen to teacher explanations outside the face-to-face classroom (pre class), in the absence of any live teacher interaction, proved problematic for some students. In particular, Student 11 noted, "I think the faults with the flipped classroom method are that if I was not understanding what the teacher was explaining than [*sic*] I could not raise my hand a [*sic*] ask a question" (S1-1). This feature, of not being able to access immediate assistance, was shared by others who referenced the ability to do this in the regular classroom. For example, "I think having it explained in class is much better because i [*sic*] can ask questions and receive information i [*sic*] wouldn't be able to in video form" (S11-1).

Cluster S4.3, *Watching video tutorials at home enables more time in class for teacher assistance,* acknowledges the advantage of shifting any passive instruction or teacher explanation out of the classroom. For example, Student 12 commented that they "prefer learning from the videos on our laptops at home because then I get more time in class to do the exercise and ask questions to the teacher about any struggles I have" (S12-2). This suggestion of more time in class with access to their teacher was reiterated by others; for example, Student 22 wrote, "When it comes to the exercises have the teacher there for assistance if needed" (S22-3).

Cluster S4.4, *Ability to seek clarification from the teacher in class after difficulties in video explanations are encountered is utilised by students,* contrasts the comments made by students in Cluster S4.2. Student 18 commented, "If you had difficulty you can just tell the teacher at school" (S18-1), suggesting that when difficulties arise at home after watching the video, students recognised they could seek their teacher's support in subsequent lessons. This was further reinforced by another student who commented, "Even if I do have some difficulties understanding something, I can always ask the teacher during our lessons" (S17-3).

The comments reported by students in this theme showed that students' perspectives about the specific features of the flipped classroom (when compared to the regular classroom) were largely positive. Students appreciated additional time availed to them to copy notes (S4.1) and the opportunity to have more time available to work on questions in class, with the assistance of their teacher during this (S4.3). Students' negative experiences were the result of encountering difficulties at home and not having immediate access to the teacher (S4.2); however, some students recognised and utilised the fact that they could discuss these difficulties with their teacher in the next lesson (S4.4).

5.1.5 Student Theme 5: Student Preferences Regarding Flipped Videos

The theme of *Student Preferences Regarding Flipped Videos* groups together students' comments about their preferences regarding the creation of the flipped classroom video tutorials, along with their personal preference for viewing. The theme comprises three clusters (Table 5.1e), which are outlined below.

Table 5.1e

Student Theme 5: Student Preferences Regarding Flipped Videos

Theme	Cluster		Students
Student Preferences Regarding Flipped Videos	S5.1	Preference for their teacher to have created the flipped video tutorials.	9
	S5.2	Students opt to watch video tutorials alone to suit their needs.	6
	S5.3	No preference for their teacher to have created the flipped video tutorials.	3

Note. "Students" is a tally of the number of students who made comments relating to a specific cluster. Some students may have made more than one comment relating to the same cluster; however, this is not recorded or represented as part of the tally (i.e., a student can only be counted once in the tally for a cluster).

Cluster S5.1, *Preference for their teacher to have created the flipped video tutorials,* contains students' comments in preference for having their teacher create the videos they watched, rather than something generic from the internet. Student 2 discussed this preference to be due to the possibility that a video from the internet "might not have been as easy to understand as it could be a different style/method to which we are use [*sic*] to" (S2-7). This comment indicates this student preferred their teacher's way of explaining concepts, and thus, their teacher creating the video was important. Other students highlighted that generic videos from the internet would not know how students learned, and that this may be problematic. For example,

> The internet the video might not make sense to me because the video wouldn't have all the detail that the students need and also the teacher knows how the students need to learn so it will make it easier for the students to learn unlike a generic video from the internet. (S18-4)

These students' comments are representative of Cluster S5.1, which highlighted the preference for Kate creating the videos. This preference appears to be the product of a level of confidence with her way of explanation that should not be traded for generically sourced content.

Cluster S5.2, *Students opt to watch video tutorials alone to suit their needs,* contains comments from students that indicate their preference to watch the video tutorials alone as it better suited their learning needs. A previous theme (Theme 2) discussed the students who watched it alone to assist their concentration and focus, whereas students through this theme indicated they watched it alone as they would find it "harder to work with someone other than my teacher" (S14-5).

Cluster S5.3, *No preference for their teacher to have created the flipped video tutorials,* highlights the views of students who indicated that it would not be vital for their teacher to have created the flipped tutorials and that they had no preference for their teacher to have created the video explanations "as long as the same information I needed was in the video" (S22-5).

Overall, the comments reported by students in this theme showed the majority of students preferred their teacher to have created the flipped video tutorials (S5.1), and this was largely due to having confidence in their teacher's ability to convey concepts in a way they would understand and assurance that the required detail for content was covered. A small group of students indicated that it would not be vital for their teacher to have made the video (S5.3); however, this was based on the caveat that there would be no compromise to the information provided. The theme also highlights a propensity for students to prefer to watch video tutorials alone.

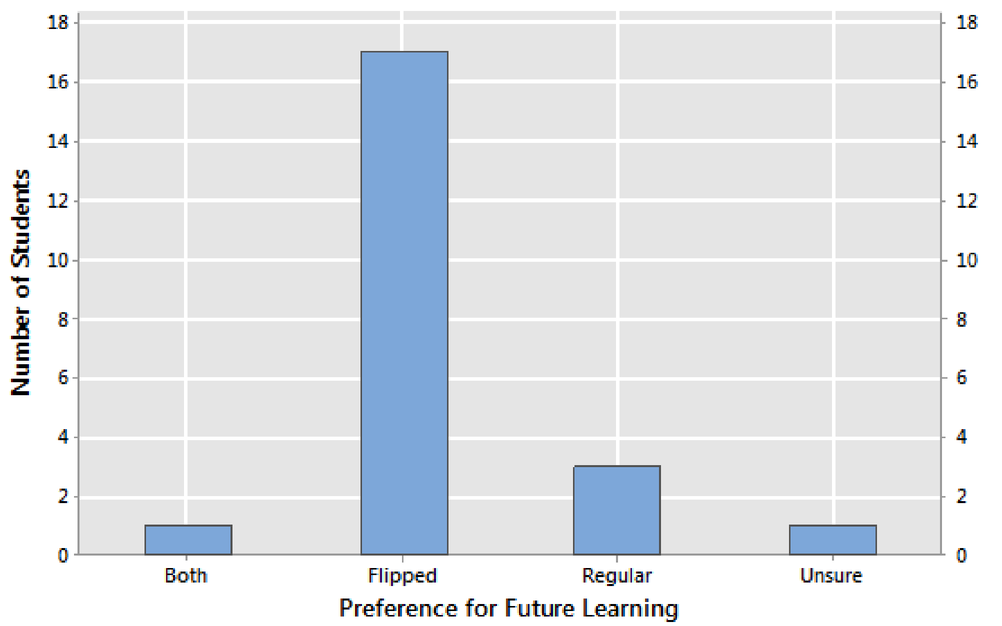
5.1.6 Student Preference for Learning

The post-topic survey provided the necessary data to provide insight into student perspectives and experiences for a range of areas through the thematic analysis. However, as part of the post-topic survey, students were questioned about how they would like to learn in future (Question 5b, post-topic survey), and these results are provided below.

Figure 4.15 shows the breakdown of student preferences, which included students nominating the flipped classroom, the regular classroom, or a mix of both. One student responded, "I don't knoq [*sic*]" (S23), and this was placed in the "unsure" category.

Figure 5.1

Student Preference for Future Learning of Mathematics



The preference for future learning data show a clear disposition of students to favour learning in a flipped classroom, which was validated through the largely positive comments in the previously discussed thematic data.

5.2 Interview Data: Teacher Experience and Perspective on the Flipped Classroom

This section presents the data obtained from the three semistructured interviews with the teacher participant, Kate. At the time of Interview 1, Kate had not yet commenced teaching the linear equations topic but had begun to create a series of flipped linear equations videos in preparation for the start of the topic. Interview 2 was timed at the halfway point of the teaching cycle for the topic. Interview 3 occurred after both groups of students had sat their post-topic test for linear equations.

The data from these three interviews have been grouped and analysed using thematic analysis (refer to Section 3.8.3). Thirteen clusters were identified across the three interviews, and these were categorised into six overarching themes, as presented in Table

5.2. The ensuing subsections provide further insight into each theme and cluster, along with representative verbatim teacher comments.

Table 5.2

Teacher Themes and Clusters

Theme		Cluster	Frequency
Requirements for the Flipped Classroom	T1.1	Clear expectations are required for student participation in the flipped classroom.	15 (1, 2, 3)
	T1.2	The need for teacher technology competency.	11 (1, 2, 3)
Understanding the Process	T2.1	Planning and preparation of lessons is more time consuming for the flipped classroom when compared to the regular classroom.	10 (1, 3)
	T2.2	Quality of videos does not need to be perfect.	6 (1, 2)
	T2.3	Viewing student progress before a face-to-face lesson can assist with a teacher's future planning and preparation.	4 (1, 2, 3)
Key Perceived Outcomes (Resources)	T3.1	Flipped tutorials are reusable.	6 (1, 2, 3)
Key Perceived Outcomes (Classroom Engagement)	T4.1	More engagement and less behavioural issues in the face-to-face class time for the flipped group when compared to the regular classroom.	11 (2, 3)
	T4.2	Flipped classroom provides collaboration opportunities.	4 (2, 3)
Key Perceived Outcomes (Teacher Specific)	T5.1	More opportunity to observe and support students' learning in the face-to-face flipped classroom when compared to the face-to-face regular classroom.	7 (1, 2, 3)
	T5.2	Teacher feels less stress in the face-to-face flipped classroom when compared with the face-to-face regular classroom.	6 (2, 3)
Key Perceived Outcomes (Learner Specific)	T6.1	Students have more time to work on questions during face-to-face class time in the flipped classroom when compared to the regular classroom.	13 (1, 2, 3)
	T6.2	The flipped classroom supports lower achieving students.	8 (1, 2, 3)
	T6.3	Flipped classroom tutorials enable flexible and individualised learning.	5 (1, 3)

Note. Frequency represents the number of paraphrased comments that relate to each cluster, with the number in parenthesis indicating which interviews these paraphrased comments originated from; that is, 5 (1, 3) means a total of five paraphrased comments formed from Interview 1 and Interview 3.

5.2.1 Teacher Theme 1: Requirements for the Flipped Classroom

The teacher theme *Requirements for the Flipped Classroom* categorises the key requirements for flipped classroom implementation based on the experiences and perspectives provided by Kate. Table 5.2a shows the two clusters in this theme that relate to the expectations necessary for Kate to provide students (T1.1) and for her to have or develop competency with technology (T1.2).

Table 5.2a

Teacher Theme 1: Requirements for the Flipped Classroom

Theme	Cluster		Frequency
Requirements for the Flipped Classroom	T1.1	Clear expectations are required for student participation in the flipped classroom.	15 (1, 2, 3)
	T1.2	The need for teacher technology competency.	11 (1, 2, 3)

Note. Frequency represents the number of paraphrased comments that relate to each cluster, with the number in parenthesis indicating which interviews these paraphrased comments originated from; that is, 5 (1, 3) means a total of five paraphrased comments formed from Interview 1 and Interview 3.

Cluster T1.1, *Clear expectations are required for student participation in the flipped classroom*, refers to the requirement for the teacher to provide clear expectations to their students to enable appropriate student participation in the flipped classroom. Kate raised initial concerns in Interview 1, speculating that if students did not watch the assigned tutorials, she would “issue a homework notification like we always do because it’s their homework and that’s what I would normally do” (T1_26). Kate’s comments suggested she would keep the expectation for homework completion the same, despite the change in homework task for the flipped students.

There were also concerns for how students would spend their class time, and that they would “waste their time in the class” given she was no longer starting with explanations. Kate therefore wanted to ensure that students understood “that this [class time] is the time that we are allowing and any work”, emphasising that any work not completed “they have to still do, obviously at home, plus watching the new tutorial and getting the notes” (T1_26).

The expectation that students would continue to be accountable for homework and work on all textbook questions in class was therefore thought about prior to flipped classroom implementation. In Interview 2, Kate indicated that she established clear expectations with her students. These were for students to

- watch the tutorial and copy the notes down in their workbook; how they watched the tutorial was left up to the students (i.e., pause or rewind as required);
- highlight difficulties prior to entering the next class so these could be clarified in class;
- complete the quiz questions from the tutorial in their workbook. (T2_03)

In addition, Kate used the viewing analytics through the Edpuzzle system to monitor student work completion. Kate noted, “Some were doing it at 6 o’clock in the morning”, and so she asked all students to have this all done the night before the next lesson as an additional expectation. At the time of Interview 2, Kate was confident these expectations were being met, and despite “a few students who did not watch the tutorial the first time round”, her continual follow-up and adherence to expectations catered to students meeting these expectations and participating in the flipped classroom as she intended. Kate commented that “by now all students know what they need to do” and “they are quite prepared actually for the next lesson” (T2_02).

In Interview 3, Kate noted that all students had met her expectations, making the comment,

> Once they got it, they got it. So, the few of them that were, you know, watching it in the same morning, that stopped. That stopped completely. They realised that others are watching it beforehand and those others were moving ahead, so they quickly went on board with that. (T3_29)

By Interview 3, Kate’s comments indicated that all students were watching the video tutorials and thus participating in the flipped classroom as she had intended. The comments provided demonstrate the movement from partial student participation in the flipped classroom in earlier interviews, with students not watching videos “first time round” (T2_02), to full implementation and participation through following teacher expectations by the end of the topic.

Cluster T1.2, *The need for teacher technology competency*, highlighted the importance of competent use of technology by the teacher as a critical requirement for the flipped classroom, with 11 paraphrased comments throughout the three interviews. In Interview 1, Kate discussed that she had spent some additional time getting used to the writing tablet used during screencasting working out, commenting that "handling everything" (i.e., Intuos and screencasting software) required a lot of time (T1_10) and it "some time to adjust" (T1_11), but that she was getting better with time.

Interview 2 revealed some aspects of technology were still proving problematic for her, with time continuing to be spent learning how to use the Edpuzzle platform. Kate mentioned she was "still learning how to get feedback from Edpuzzle of the student's ongoing progress" (T2_04). This feedback relates to student viewing data and their responses to the assigned quiz questions, which were vital for Kate being able to establish homework expectations as discussed in T1.1.

By Interview 3, these issues were no longer prevalent. Through her experience with implementing a technology-enabled flipped classroom, Kate reflected on the initial start-up difficulties in implementing the flipped classroom, which were having an understanding of

> the tools you need; they need to be able to sort of manage all of them and make your notes clear for the students, or else you spend a lot of time preparing notes and the students still won't get it. (T3_21)

This comment suggests that while teachers can understand how to use certain aspects of technology, they need to be fluent in its use. For example, the writing tablet tool needed to be managed alongside a voiceover, with clear handwriting on the tablet to ensure students could make sense of the final product.

Overall, the requirements for a flipped classroom appear multifaceted. Teachers are required to establish expectations, even if these expectations are the same as before (i.e., complete assigned homework), and continue to maintain these standards for full participation in the flipped classroom. Additionally, teachers are required to be technologically competent. They need to be fluent in the use of technology so that they can access analytics and create videos that are useful for students.

5.2.2 Teacher Theme 2: Understanding the Process

The theme *Understanding the Process,* highlights the importance of processes such as the planning, preparation, and creation of lessons and videos. These processes were separated into three specific clusters (see Table 5b) that provided the insight that a teacher should understand or be aware of when implementing a flipped classroom.

Table 5.2b

Teacher Theme 2: Understanding the Process

Theme		Cluster	Frequency
Understanding the Process	T2.1	Planning and preparation of lessons is more time consuming for the flipped classroom when compared to the regular classroom.	10 (1, 3)
	T2.2	Quality of videos does not need to be perfect.	6 (1, 2)
	T2.3	Viewing student progress before a face-to-face lesson can assist with a teacher's future planning and preparation.	4 (1, 2, 3)

Note. Frequency represents the number of paraphrased comments that relate to each cluster, with the number in parenthesis indicating which interviews these paraphrased comments originated from; i.e., 5 (1, 3) means a total of five paraphrased comments formed from Interview 1 and Interview 3.

Cluster T2.1, *Planning and preparation of lessons is more time consuming for the flipped classroom when compared to the regular classroom,* has 10 comments across Interviews 1 and 3 that highlights Kate's concerns about the additional time needed for planning and preparation compared to her regular approach. In Interview 1, when Kate was planning and preparing the majority of her video tutorials, she mentioned that given her experience, it would generally take her around 5 minutes to prepare a 50-minute lesson with her regular approach; however, the flipped classroom was "definitely more lengthy than the 5 minutes" (T1_10). The additional time was described to come from two areas:

- Writing and preparing planning notes on what to do in the video, as Kate mapped out what notes would go in each tutorial, commenting that "preparing the notes . . . written . . . took for sure about 2 to 3 hours to prepare for a whole unit" (T1_30);

- Getting all the technological aspects in working order for a video, commenting that "the first video probably took me . . . 2 hours, umm, because I couldn't get everything sort of aligned together, video and pen and everything" (T1_28).

In Interview 3, Kate maintained it was a time-consuming process to implement the flipped classroom, with the creation of video tutorials consuming the most time. However, although time consuming, Kate acknowledged, "It's worth the time spending preparing for the flipped classroom" (T3_01).

Cluster T2.2, *Quality of videos does not need to be perfect,* highlights the need not to spend too much time trying to make videos perfect when attempting to create video explanations. Kate mentioned in Interview 1 that a large portion of time had been devoted to trying to make the videos perfect, and any imperfections in her voiceover caused her to start recordings from the start. It was not until after around five lessons that Kate accepted being "less perfect, so if a mistake was done I would just say no this is the way it needs to be done, rather than just starting from scratch" (T1_11). In Interview 2, Kate mentioned she sought feedback on what the students thought of the way she had created the videos, and they provided her with positive feedback, reinforcing the notion that they do not need to be perfect. This is evidenced through Kate's reflection on student comments in class when prompted about video quality:

> They have been "nah we like them Miss", "we can understand them", "there's enough examples" and I can tell that because they can then go straight into their work after we've reviewed the quiz questions, umm—so yeah, the feedback was good. (T2_06)

Cluster 2.3, *Viewing student progress before a face-to-face lesson can assist with a teacher's future planning and preparation,* summarises Kate's ideas about how the process of planning and preparation was enhanced through the ability to view student progress before face-to-face lessons. Kate outlined in Interview 1 that she would use the Edpuzzle analytics to help inform future focus areas in her lesson planning, and in Interview 2 commented that she had been using student progress in the embedded quiz questions to guide discussion in the next face-to-face class, stating that she "will show them … how many of you got this one incorrect, let's discuss it on the board" (T2_25). Kate also mentioned there was nothing surprising about what students were getting right or wrong, and any incorrect responses were anticipated (T2_26, T2_27).

While they may not have been surprising for the teacher, the use of student progress to inform future planning was further highlighted in Interview 3:

> When we did the transposing of equations, the flipped group—I had to go through the tutorial again with them in class, because they got most of the questions, the quiz questions incorrect. And so . . . we discussed extra examples on the board, and once I explained it on the board, then they said "oh now I get it". (T3_07)

This theme showed that teachers should be aware of the process involving flipped classroom implementation, expecting that it will consume more time than their regular approach (T2.1) but highlighting that videos do not need to be perfect (T2.2) for students to appreciate. It also showed the benefits that can flow from implementation, with a potential to observe student progress prior to entering the class (T2.3).

5.2.3 Teacher Theme 3: Key Perceived Outcomes (Resources)

The theme of *Key Perceived Outcomes (Resources)* suggests the potential outcomes of the flipped classroom, with a specific focus on the use of created resources from Kate's perspective. There is one cluster in this theme, concerning Kate's comments on the reusable nature of flipped tutorials (see Table 5.2c).

Table 5.2c

Teacher Theme 3: Key Perceived Outcomes (Resources)

Theme	Cluster	Frequency
Key Perceived Outcomes (Resources)	T3.1 Flipped tutorials are reusable.	6 (1, 2, 3)

Note. Frequency represents the number of paraphrased comments that relate to each cluster, with the number in parenthesis indicating which interviews these paraphrased comments originated from; i.e., 5 (1, 3) means a total of five paraphrased comments formed from Interview 1 and Interview 3.

Cluster T3.1, *Flipped tutorials are reusable*, has six paraphrased comments from the three interviews. Kate commented that tutorials can be reused year-to-year as a standout advantage of creating a video in addition to being able to use them for different groups of students within the same year. While these advantages were discussed in Interview 1, Kate mentioned in Interview 2 that she had been able to assign tutorials for absent students, commenting that the videos "have already been useful for those students who weren't there" (T2_32), indicating the practical usefulness of reusable tutorials.

In Interview 3, Kate reemphasised these advantages but also commented on the benefits for teachers with multiple class groups at the same year level, stating,

> When you've got the same class, you know you've got two or three of the same classes as well. It is quite efficient to have the tutorials—because to repeat the same things twice or three times a day—it can be draining.

While this theme has only one cluster, the comments in this cluster were important for understanding the specific resource outcomes of flipped classroom implementation. The reusable nature of resources is beneficial for teachers and students.

5.2.4 Teacher Theme 4: Key Perceived Outcomes (Classroom Engagement)

The theme *Key Perceived Outcomes (Classroom Engagement)* focuses on the outcomes that impacted specifically on student classroom engagement from the teacher's perspective. Kate's comments from observations of student interactions in the face-to-face classroom are provided through two clusters (see Table 5.2d).

Table 5.2d

Teacher Theme 4: Key Perceived Outcomes (Classroom Engagement)

Theme	Cluster		Frequency
Key Perceived Outcomes (Classroom Engagement)	T4.1	More engagement and less behavioural issues in the face-to-face class time for the flipped group when compared to the regular classroom.	11 (2, 3)
	T4.2	Flipped classroom provides collaboration opportunities.	4 (2, 3)

Note. Frequency represents the number of paraphrased comments that relate to each cluster, with the number in parenthesis indicating which interviews these paraphrased comments originated from; i.e., 5 (1, 3) means a total of five paraphrased comments formed from Interview 1 and Interview 3.

Cluster T4.1, *More engagement and less behavioural issues in the face-to-face class time for the flipped group when compared to the regular classroom,* contained 11 paraphrased comments across Interviews 2 and 3, which focused on Kate’s observation that there were less behavioural issues in the face-to-face classroom for the flipped group when compared to the regular classroom. Despite not anticipating improved engagement as an advantage in Interview 1, Kate referred specifically to improved behavioural engagement in Interview 2:

> The behaviour in the flipped group, I think it has improved—you know they work straight through then they ask for a break, they come back in and then they keep working. Whereas the other group, there is still that struggle, once you finish off the explanation they want a break, because they’ve had, you know, almost enough, and then they still need to start working. Yeah, so in the flipped group, the behaviour is much better. (T2_33)

The disparity in behavioural engagement between the two classes was further reinforced through Interview 3, with Kate commenting, “The flipped group were more engaged in their work. They were really, you know, heads down and just completing their work” (T3_12), whereas in the regular classroom, “When it’s time for them to start working, they’re tired by then, they’re tired of it all—so I had to push them to—to encourage them to use their time more efficiently” (T3_10).

The second cluster, T4.2, *Flipped classroom provides collaboration opportunities*, centres on Kate’s observation that the students tended to collaborate with each other more in the flipped classroom. These comments appeared in Interviews 2 and 3. Reflective of these observations was *Kate’s* comment in Interview 2 that “students are helping each other more, I noticed, because obviously they’ve watched the video—they’ve understood it—and then they might be feeling more comfortable helping out each other” (T2_09). In Interview 3, Kate commented that when walking around the classroom, her perception was that students were “helping out each other” (T3_09), highlighting that the student collaboration was ongoing through the flipped implementation.

This theme showed, from Kate's perspective, students in the flipped classroom had heightened behavioural engagement (T4.1) and collaboration with one another in the face-to-face classroom (T4.2).

5.2.5 Teacher Theme 5: Key Perceived Outcomes (Teacher Specific)

The theme of *Key Perceived Outcomes (Teacher Specific)* focuses on outcomes of the flipped classroom that were specific to the teacher, such as an enhanced ability to support students and a feeling of reduced stress in classes. There are two clusters in this theme (see Table 5.2e).

Table 5.2e

Teacher Theme 5: Key Perceived Outcomes (Teacher Specific)

Theme		Cluster	Frequency
Key Perceived Outcomes (Teacher Specific)	T5.1	More opportunity to observe and support students learning in the face-to-face flipped classroom when compared to the face-to-face regular classroom.	7 (1, 2, 3)
	T5.2	Teacher feels less stress in the face-to-face flipped classroom when compared with the face-to-face regular classroom.	6 (2, 3)

Note. Frequency represents the number of paraphrased comments that relate to each cluster, with the number in parenthesis indicating which interviews these paraphrased comments originated from; i.e., 5 (1, 3) means a total of five paraphrased comments formed from Interview 1 and Interview 3.

Cluster T5.1, *More opportunity to observe and support students learning in the face-to-face flipped classroom when compared to the face-to-face regular classroom,* was mentioned in all three interviews. This cluster focused on Kate's increased ability to observe and support students' learning in the face-to-face flipped classroom. In Interview 1, Kate mentioned the regular group would be at a disadvantage completing questions "when they are at home working by themselves and the teacher is not there" (T1_16), and the flipped group would be at an advantage by being able to learn at home and subsequently "have more time to complete class work . . . with my assistance" (T1_16). Interviews 2 and 3 continued this line of commentary, with Kate commenting on the flipped students' increased ability to just "put their hand up and there's my help" (T2_07), which was not readily available for the regular group. This enhanced notion of assistance from Kate was largely due to her being able to “get a feel more from the flipped group because I’m seeing them doing their work in front of me” (T2_11). This was not possible in the regular group, where they mostly completed their work for homework due to content explanations consuming the bulk of time.

The second cluster in this theme, T5.2, *Teacher feels less stress in the face-to-face flipped classroom when compared with the face-to-face regular classroom,* concerns the comments that Kate made about her sense of stress and wellbeing as a result of implementing the flipped classroom. Six paraphrased comments in Interviews 2 and 3 formed this cluster, with Kate highlighting “that going into the flipped class I am less stressed with the fact that I’m not time constrained with, you know, oh we need to get through this, this and this” (T2_30), contrasting with the regular class, where she found it was “always sort of a struggle” (T2_30). These comments ultimately centred on a time stress of having to get through content in a finite amount of time, which was not felt in the flipped classroom.

The key perceived outcomes through these themes showed a teacher-specific impact through a heightened ability to observe and support students as they worked (T5.1), alongside a reduction in stress in the flipped classroom largely driven by reduced time pressures (T5.2).

5.2.6 Teacher Theme 6: Key Perceived Outcomes (Learner Specific)

The theme of *Key Perceived Outcomes (Learner Specific)* focuses on the potential outcomes of the flipped classroom that were specific to the students, as perceived by the teacher. Three clusters formed this theme (see Table 5.2b).

Table 5.2f

Teacher Theme 6: Key Perceived Outcomes (Learner Specific)

Theme		Cluster	Frequency
Key Perceived Outcomes (Learner Specific)	T6.1	Students have more time to work on questions during face-to-face class time in the flipped classroom when compared to the regular classroom.	13 (1, 2, 3)
	T6.2	The flipped classroom supports lower achieving students.	8 (1, 2, 3)
	T6.3	Flipped classroom tutorials enable flexible and individualised learning.	5 (1, 3)

Note. Frequency represents the number of paraphrased comments that relate to each cluster, with the number in parenthesis indicating which interviews these paraphrased comments originated from; i.e., 5 (1, 3) means a total of five paraphrased comments formed from Interview 1 and Interview 3.

Cluster T6.1, *Students have more time to work on questions during face-to-face class time in the flipped classroom when compared to the regular classroom,* highlights Kate's perception that students in the flipped classroom had more time to work on their assigned questions during face-to-face lessons. Kate first speculated this as being a potential advantage in Interview 1 (see T1_14). Kate commented on her observations after implementing the flipped classroom, confirming her initial thoughts. The following excerpt is reflective of the comments in Interviews 2 and 3.

> So with the flipped group, I would probably say out of a double period [100 minutes] we're, maximum spending, 20 minutes if I see that they had difficulties with the quiz questions. Um, whereas with the other class having to go through the difficulties from the last lesson and then through the content and then I would say that maybe they end up with 20 minutes of doing work, so that's a big difference. (T2_12)

Cluster T6.2, *The flipped classroom supports lower achieving students,* focuses on the comments Kate made about lower achieving students being better supported through a flipped classroom. After flipped classroom implementation, Kate mentioned the positive impact observed in the flipped classroom for lower achieving students, noticing that they were "doing quite well" (T2_09), which Kate commented was unusual for one particular student, who would otherwise not do any work when encountering difficulty.

Cluster T6.3, *Flipped classroom tutorials enable flexible and individualised learning*, highlights the ability of the flipped classroom to support individualised learning for students. Through Interview 1, Kate mentioned a perceived benefit for the flipped classroom in better catering for absent students, along with the ability for all students to "access the examples and the tutorials at any time they want to, and as many times as they want to" (T1_16). Interview 3 confirmed that she felt students were able to achieve better outcomes "because they could you know, watch the tutorials at their own pace, as many times as they want" (T3_02), which then "allowed me to help them more in class" (T3_02).

This theme showed the learner specific outcomes, as perceived by the teacher, to extend from an innate ability for students in the flipped classroom to have more time to work on questions in class (T6.1) and a heightened support for lower ability learners (T6.2). Furthermore, the capacity for individualised learning was noted and could be better supported by the teacher (T6.3).

Chapter 6.

Discussion

This chapter analyses and discusses the four broad aspects of this research—student understanding, attitude, and perspective and teacher experience data—as presented through Chapters 4 and 5. The first two sections of this chapter (Sections 6.1 and 6.2) focus on student understanding of solving linear equations. Students' understanding in the flipped and regular groups is established and compared before and directly after the linear equations topic (Section 6.1; RQ1), before comparing the retention in understanding for each group (Section 6.2; RQ2). Students' attitudes to learning mathematics with technology are then compared before and after the linear equations topic (Section 6.3) to determine any differences between the groups (RQ3). The themes generated from the open-ended questions on the post-topic survey are then discussed in Section 6.4 to determine students' perspectives on the flipped classroom (RQ4). Finally, teacher experience and perspective are explored in Section 6.5 through the discussion of teacher themes developed over the three semistructured interviews (RQ5). The responses to each research question are then provided in Chapter 7.

6.1 Student Understanding: Quizzes A and B

Student understanding of solving linear equations in this research encompasses both the stage of understanding and MKG data (Section 3.8.1). Quizzes A and B understanding data, as presented in Chapter 4, are analysed and discussed through this section to gain insight into the similarities and differences that were apparent between the flipped and regular groups immediately before and after the solving linear equations topic (RQ1).

6.1.1 Student Stage of Understanding

Students' responses to Quizzes A and B were analysed by the SMART test system and categorised into five stages of understanding (as described in Section 3.5.1); an overview of these stages along with a description of the demonstrated student understanding is summarised in Table 6.1.

Table 6.1

Overview for Each Stage of Understanding for Solving Linear Equations

Stage of Understanding	Qualitative Descriptor	Descriptor
Stage 0	None	Students are unable to solve the simplest of linear equations, including those that are able to be solved through guess-and-check methods.
Stage 1	Basic	Students can solve simple linear equations that are easy to solve by guessing,
Stage 2	Developing	and can solve linear equations with more difficult answers so that a systematic method such as backtracking is required,
Stage 3	Complex	and can solve linear equations with pronumerals on both sides and only addition symbols, so that they need to be solved by "subtracting the same from both sides",
Stage 4	Complete	and can solve linear equations with pronumerals on both sides where constants and/or coefficients can be negative, so that they need to be solved by "doing the same to both sides".

Note. Adapted from "Developmental Stages and Teaching Suggestions" by K. Stacey et al., 2011a (http://www.smart-quiz.edu.au/teacher). Copyright 2011 by SMART research.

Table 6.2 provides a side-by-side comparative summary of the number of students in each group who were diagnosed with each stage of understanding for Quizzes A and B. These data summarise the data presented in Figure 4.16 and Figure 4.17 in Chapter 4.

Table 6.2

Comparative Summary for Number of Students Diagnosed at Each Stage for the Flipped and Regular Groups for Quizzes A and B

	Flipped Group		**Regular Group**	
Number of Students for Each Stage of Understanding	**Pre Topic Quiz A (*n* = 22)**	**Post Topic Quiz B (*n* = 22)**	**Pre Topic Quiz A (*n* = 23)**	**Post Topic Quiz B (*n* = 23)**
Stage 0 (None)	1	1	6	3
Stage 1 (Basic)	7	2	10	3
Stage 2 (Developing)	8	0	5	0
Stage 3 (Complex)	6	13	2	12
Stage 4 (Complete)	0	6	0	5

6.1.1.1 Flipped Group Understanding

The pre-topic data from Table 6.2 identify 16 students (~73% of students in the group) in the flipped group to have a Stage 2 (Developing) or lower understanding before commencing the linear equations topic, with only six students having a Stage 3 (Complex) or Stage 4 (Complete) understanding. From Table 6.1, a Developing (or lower) stage of understanding can be considered primarily grounded in arithmetical thinking, with the use of more informal methods of solving such as trial-and-error substitution (see Section 2.1.2 for a list of methods). The use of more informal methods of solving is indicative of the cut-points in thought processes (Filloy & Rojano, 1989) or the cognitive gap (Herscovics & Linchevski, 1994) as it reflects students' inability to utilise the required method to move from arithmetical approaches to algebraic (non-arithmetical) approaches (see discussion in Section 2.1). This result was expected given students in Year 9 at School A had not studied solving linear equations with pronumerals on both sides of the equals sign through their previous years of schooling.

The post-topic data in Table 6.2 show a substantial improvement to student understanding in the flipped group, with only three students diagnosed as having a

Developing or lower understanding directly after the linear equations topic, and 19 students diagnosed with a Complex or Complete understanding. Given that three students did not demonstrate the understanding required to progress beyond a Developing understanding in Quiz B, it becomes important to understand their situation in more detail. Figure 4.16 highlights that of these three students, two did not progress from their initially identified stage (Stage 1 and Stage 0), and the third student decreased from a Stage 3 to a Stage 1 understanding between Quizzes A and B. The time spent viewing tutorial data, as described in Section 3.7.3 and presented in Appendix K, offers some explanation towards this lack of progression in understanding. The two students who had failed to progress in their stage of understanding (Student 8, Stage 0; Student 14, Stage 1) had the lowest viewing times of all students in the class and were the only students with less than 1 hour viewing time (49 minutes and 8 minutes, respectively). The total video duration available was 73 minutes and 48 seconds (Appendix J), so the minimum student viewing time should have been reported as 1 hour for students who had viewed all provided tutorials once (see Section 3.7.3). The unchanged stage of understanding for these two students could therefore be accounted for by the lack of tutorial access given that watching the video tutorials was the primary means for students to gain instruction and guided examples from their teacher.

Although the above explanation can help to account for these two students' understanding, it cannot account for the only student who decreased in their stage of understanding between Quizzes A and B (Student 18; from Stage 3, Quiz A to Stage 1 Quiz B). This student was one of two students whom the Edpuzzle platform had reported to have spent the longest time viewing the content (2 hours). Given the viewing data were collected at the end of Quiz C testing (see Section 3.7.3) and that Student 18 eventually increased their stage of understanding in Quiz C to Stage 3 (see Section 6.2.1), this viewing time may be the result of re-watching videos between Quiz B and the time of Quiz C; however, this data were not available in this research (Section 3.7.3).

In summary, improvements to student understanding were observed in the flipped group between Quizzes A and B. This was evidenced by 19 students demonstrating a Complete or Complex understanding at Quiz B compared with only six students at the time of Quiz A (Table 6.2). The improvement in the flipped group was further exemplified by the 17 students who were diagnosed with at least one stage increase in understanding between Quizzes A and B (Figure 4.16). This outcome suggests that, for the majority of the flipped group, a flipped classroom approach was effective in developing student understanding for solving linear equations.

6.1.1.2 Regular Group Understanding and Comparison With the Flipped Group

The pre-topic assessment for the regular group shows 21 students to have a Developing (or lower) stage of understanding before commencing the linear equations topic (Table 6.2; Quiz A), which is five more students in comparison with the flipped group. These results, as was the case in the flipped group, indicate the majority of students in the regular group had an understanding that was grounded in arithmetical strategies before the linear equations topic. Both the flipped and regular group results are to be expected when taken in consideration with research findings that the equivalence notion of the equals sign (Kieran, 1981) does not come easily for some students, and the strategies to solve the non-arithmetical equations do not come spontaneously for students either (Filloy & Rojano, 1989). The development (and need for development) of this understanding is unlikely to have occurred given that it had not been part of the mathematics curriculum at School A.

The post-topic data reveal a similar improvement in understanding for the regular group as was observed in the flipped group, with only six students diagnosed with a Developing or lower understanding after Quiz B (compared to 21 at Quiz A; Table 6.2). One student moved from a diagnosis of no understanding (Stage 0) to Complete understanding (Stage 4) between Quizzes A and B (see Figure 4.17)—a magnitude of progression that was not seen in the flipped group. However, as was the case with the flipped group, the regular group was unsuccessful in increasing the stage of understanding for all students (Figure 4.17). Five students (one Stage 0, three Stage 1, and one Stage 3) remained unchanged in their diagnosed stage of understanding between Quizzes A and B for the regular group (compared with four students in the flipped; Figure 4.16). Two students decreased in their understanding in the regular group (both students from Stage 1 to 0; Figure 4.17) compared with one in the flipped (Stage 3 to Stage 1; Figure 4.16). However, while the unchanged stage for the two students with a Developing understanding in the flipped group was accounted for by their reduced viewing time of video tutorials, there was no accountability measure (i.e., lack of viewing time) for the four students in the regular group who did not progress from a Developing or lower understanding. Furthermore, given the regular group had a higher number of students from Quiz A with a stage diagnosis of Developing or lower, there was greater potential to observe growth between Quizzes A and B. However, this was not observed. Overall, 16 students increased in their stage of understanding between Quizzes A and B in the regular group (compared with 17 in the flipped group).

Nonetheless, with such a large number of students completing the topic with a Complex or Complete understanding in the regular group (17 students at Quiz B compared to two at Quiz A), it is reasonable to conjecture that the regular classroom approach had been effective in progressing student understanding. Both the flipped and regular groups were able to produce a similar proportion of students with a Complete understanding after teaching (six students vs five students, respectively; see Table 6.2). This progression in understanding highlights the potential of both Kate’s flipped and regular approaches to bridge the didactic cut and help her students to develop the strategies necessary to solve non-arithmetical-style equations.

Using the pre- and post-topic stage of understanding data, both the flipped and the regular approach appear equally effective at progressing students from a Developing or lower stage of understanding to a Complex or Complete understanding. This increased understanding indicates a shift in understanding for students in both groups. The movement between lower level stages to higher level stages of understanding requires students to transition from arithmetical understanding to algebraic (non-arithmetical) understanding (see Section 2.1), and thus, these student results indicate an increased capacity to apply formal methods to solve non-arithmetical equations. Given the flipped group had more access to teacher support, we may have expected the post-test to highlight a greater understanding, but this was not the case. The benefits of the flipped classroom in this research became more apparent in the delayed test (Quiz C), where they were able to better retain this understanding.

Furthermore, research that has examined student achievement has reported lower achieving students to perform better in flipped high school mathematics when referenced to control groups (see Bhagat et al., 2016; Jensen et al., 2015). This was not observed through comparison of Quiz A and B results in the flipped and regular groups in this research. However, there were also no targeted teaching interventions in this research unlike those undertaken in other studies (e.g., Bhagat et al., 2016). Kate commented that she believed the flipped classroom to be of greatest benefit to lower ability learners. In particular, she mentioned one student in the flipped group to have made significant gains on the questions completed in class throughout the topic. This student was identified as having a Stage 1 understanding before the linear equations topic (Quiz A) however was not represented in these data due to being absent for Quiz B. Any of this student's growth, and Kate's observations, was therefore unable to be further substantiated by this research. Based purely on the stages of understanding that were determined through Quizzes A and B, there is no clear indication that any one group of learners was at any particular advantage or disadvantage through either teaching approach.

6.1.2 Misconceptions and Knowledge Gap: Comparisons Between Flipped and Regular Groups

The MKG data supplement the stage of understanding data to help provide an overall representation of student understanding of solving linear equations. The importance of helping to eradicate misconceptions for furthering student understanding was alluded to by Linsell (2009) when discussing the importance for teachers to understand student success in solving two-step equations (i.e., non-arithmetical equations), stating, "It is important for teachers to appreciate that success at solving two-step equations does not necessarily imply that students fully understand the strategy of working backwards. In fact some students can solve two-step equations only by guess and check" (p. 337). Linsell's point is pertinent to emphasise given success for non-arithmetical types of equations relates to students who have achieved Stage 3 or Stage 4; however, the stage data alone provide no explicit insight into how an equation was solved. Diagnosing misconceptions, therefore, can provide further insight into student understanding.

Nonetheless, and regardless of the strategy used to solve, misconceptions will continually present issues to students in their attempts to solve linear equations. The collated MKG data for Quiz A (Table 4.4) and Quiz B (Table 4.5) are summarised in Table 6.3 for each group.

Table 6.3

Misconception or Knowledge Gap Frequency for the Flipped and Regular Groups: Quizzes A and B

	Flipped Group (*n* = 22)		**Regular Group (*n* = 23)**	
Misconception or Knowledge Gap	**Pre Topic Quiz A Frequency**	**Post Topic Quiz B Frequency**	**Pre Topic Quiz A Frequency**	**Post Topic Quiz B Frequency**
SE	18	7	21	9
AES	10	2	8	2
BES	7	0	2	2
RES	5	0	1	0
AF	0	7	2	5
Total	40	16	34	18

Note. SE = simplification error, AES = addition equation solution, BES = bracketless equation solution, RES = reverse equation solution, AF = algebraic fraction. Up to 22 flipped group students and 23 regular group students could be diagnosed with each MKG.

In Chapter 4, it was found that the overall number of students diagnosed with an MKG was similar between the groups for Quiz A. Of the 22 students, 20 (91% of students) in the flipped group were diagnosed with at least one form of MKG (Quiz A; Table 4.4). This was comparable with the regular classroom, in which all 23 students (100% of students) were diagnosed with an MKG (Quiz A; Table 4.5). While this demonstrates the number of students with an MKG to be slightly higher in the regular group, Table 6.3 shows the flipped group to have a slightly higher incidence of MKGs on Quiz A (40 MKGs) when compared to the regular group on Quiz A (34 MKGs). Following the linear equations topic, the flipped group demonstrated a greater reduction in the incidence of MKGs, with 24 fewer incidences in the flipped (Quiz B; Table 6.3) and 16 fewer incidences in the regular (Quiz B; Table 6.3). Given that there were five MKGs measured through this research, it is essential to consider these separately to better understand the influence each teaching approach had in addressing each MKG.

The most substantial reduction in the frequency of MKGs for both groups was the result of fewer SE misconceptions, with 11 fewer in the flipped (Quiz B; Table 6.3) and 12 fewer in the regular. The reduction in SE misconceptions, alongside neither group having any student develop the misconception between Quizzes A and B, indicates both teaching methods were comparably effective in being able to develop algebraic understanding, without introducing or reinforcing an SE misconception. Despite fewer occurrences when compared to Quiz A, the SE misconception remained the most frequently diagnosed MKG for both groups (equal highest with AF in the flipped group).

A similar reduction in the incidence of AES misconceptions was also observed for the flipped (eight fewer) and regular groups (six fewer), with only two students in each group diagnosed with the misconception on Quiz B (Table 6.3). In both groups, one student retained their AES misconception in Quiz A and Quiz B, and another student was diagnosed with the misconception in Quiz B (see Table 4.4 and 4.5). The similar reduction and gain of the AES misconception for students in both groups once again highlights the comparable effectiveness of Kate's regular and flipped approaches, with students demonstrating an increased capacity to solve equations in the form $x - a = b$.

The RES misconception had a 100% reduction for both the flipped and regular groups, with no student in either group diagnosed with this misconception in Quiz B. This demonstrates that both the flipped and regular teaching approach helped students learn to apply appropriate methods to solve equations in the form $a - x = b$. This helps to demonstrate the notion that more formal strategies of solving can be utilised after learning in either the flipped or regular classroom.

The reduced incidence observed for the AES, SE, and RES misconceptions in Quiz B for both groups (Table 6.3) was not evident for the BES misconception. Two students in the regular group (Student 10 and Student 12) who demonstrated the BES misconception in Quiz A no longer did so on Quiz B (Figure 4.5). However, two other students were diagnosed with the BES misconception in Quiz B. This was in contrast to the flipped group who had no instances of BES misconceptions during Quiz B, despite having seven students with the misconception in Quiz A (Table 6.3). The students in the flipped group therefore demonstrated an increased capacity to solve equations of the form $a(x + b) = c$ when compared to the regular group who had students develop the misconception after the linear equations topic. When considering the development of algebraic understanding, this is an important misconception to dispel, as errors in being able to expand brackets accurately will ultimately impact a student's ability to solve any type of linear equation involving brackets, whether arithmetical or non-arithmetical. This could hinder student algebraic understanding in future years when the reliance for expansion and factorisation is increased (i.e., solving quadratic equations in factored forms).

The AF knowledge gap was the only MKG to increase in frequency between Quizzes A and B for both groups (Table 6.3). Two students in the regular group had retained their previously identified AF misconception from Quiz A (Table 4.5), and an additional three students were diagnosed in Quiz B, bringing the total to five students in the regular group with an AF knowledge gap (Table 6.3). This is a slightly different scenario to the flipped classroom students, which had no students diagnosed with AF before the topic and seven diagnosed in Quiz B. This increase suggests that both teaching approaches were somewhat ineffective in addressing this knowledge gap. The increased diagnosis of AF in the flipped group could potentially point to issues for the flipped approach to effectively address the AF knowledge gap. However, given that both groups increased and both were taught using the same explanations and examples, it could be plausible to suggest the teaching explanations and examples (and not necessarily the approach) were the contributing factors in this instance. The examples and explanations may not have covered the necessary knowledge required for students to appropriately solve equations of the form $x/a + b = c$ and/or $(x + a)/b = c$, and this may have contributed to the increase in AF diagnoses for both groups.

6.2 Student Understanding: Quizzes B and C

The Quiz C stage of understanding data provided insight into the extent to which students retained, increased, or decreased their previously diagnosed Quiz B stage of understanding after 3 weeks. There was slight attrition of students in each group due to absence in the school term, resulting in two fewer students in the flipped group (20 students total) and one fewer student in the regular group (22 students total). The discussion and analysis presented in this section provides the necessary information to determine student retention in understanding (RQ2).

6.2.1 Student Stage of Understanding

Table 6.4 provides a side-by-side summary of the number of students in each group diagnosed with each stage of understanding for Quizzes B and C. These data summarise the data presented in Figures 4.18 and 4.19.

Table 6.4

Comparative Summary for Number of Students Diagnosed at Each Stage for the Flipped and Regular Groups for Quizzes B and C

	Flipped Group (*n* = 20)		**Regular Group (*n* = 22)**	
Stage of Understanding	**Post Topic Quiz B Frequency**	**Delayed Test Quiz C Frequency**	**Post Topic Quiz B Frequency**	**Delayed Test Quiz C Frequency**
Stage 0 (None)	1	2	3	5
Stage 1 (Basic)	2	0	3	1
Stage 2 (Developing)	0	1	0	3
Stage 3 (Complex)	11	8	12	5
Stage 4 (Complete)	6	9	4	8

Note. The number of students available at the time of Quiz C was lower than the time of Quiz B, so some students' results have been omitted to ensure an appropriate comparison between time points (see Section 3.8.1).

6.2.1.1 Flipped Group Understanding

Analysis of the Quiz C data for students in the flipped group revealed the same number of students with a Developing or lower level of understanding as observed in Quiz B (three students). Of these three students, two (Student 8 and Student 14) were the same students identified in Section 6.1 as not accessing the minimum video duration of the flipped tutorials. Retaining a low-level of understanding could be expected for these two students as they had failed to access the video explanations, which was the primary means for content explanation or instruction. Therefore, the demonstrated lower understanding is reflective of their limited engagement with the tutorial content. This disengagement is similar to that reported by Lo and Hew (2017), who noted students failing to access pre-class content and subsequently becoming disengaged from classroom work and activities. The third student (Student 13) who demonstrated a Developing understanding in Quiz C had decreased from a Complex understanding at Quiz B. The time analytics data from Edpuzzle indicated that Student 13 had accessed at least 1 hour of content; however, it was unable to provide information on when the student had accessed their work. While speculative, it is plausible to assume that given they did not have a Complete understanding at Quiz B, any shortcomings in understanding may have been exacerbated over a longer duration, and thus they subsequently regressed by not re-accessing content within the 3-week delay for Quiz C.

Overall, three students decreased one stage from their Quiz B assessment result. Seven students who had room to progress in their understanding (i.e., they were not at Stage 4 in Quiz B) retained the same stage of understanding as identified in Quiz B, and five students progressed at least one stage of understanding. This distribution resulted in 17 of 20 students (85% of students) diagnosed with a Complex or Complete understanding, which is the same proportion of students when compared with Quiz B. This suggests a strong capacity for the flipped approach to help students develop Complex and Complete understanding, which they retained over a 3-week period.

6.2.1.2 Regular Group Understanding and Comparison With the Flipped Group

Table 6.4 shows the regular classroom increased in the number of students diagnosed with a Developing or lower level of understanding for Quiz C (nine students) when compared to Quiz B (six students). This result was less favourable than the flipped group, which maintained the same number of students at these lower stages of understanding (three students). Additionally, the regular group had eight students that decreased at least one stage (Figure 4.19). This again was more substantial than the flipped group, which had three students decrease in understanding (Figure 4.18). Overall, the flipped group had fewer students who decreased in their stage of understanding compared to the regular group (three students compared with eight students). There did not appear to be any particular stage of understanding impacted any more than another, with both the flipped and regular groups demonstrating student decreases at all stages. However, students who decreased in understanding in the regular group tended to decrease to a greater extent than those in the flipped group. For example, all three decreases in the stage of understanding for the flipped group were decreases of one stage, whereas the regular group produced decreases of one stage for six students, two stages for one student, and three stages for another. This suggests an inability for the regular classroom to retain students' understanding after 3 weeks compared to the flipped classroom.

The changes to the distribution of diagnosed stage of understanding for students in the regular group in Quiz C resulted in a lower proportion of students diagnosed with a Complex or Complete understanding when compared with Quiz B (Table 6.4). Of 22 students, 13 (59% of students) in the regular group were diagnosed with a Complex or Complete understanding in Quiz C, which is three fewer than at Quiz B. In contrast, the flipped group had 17 of 20 students (85%) diagnosed with a Complex or Complete understanding (Table 6.4). Differences in demonstrated stages of understanding could be due to the flipped approach better developing student understanding initially, and this may have resulted in better retention over time. However, it could also be the result of the flipped group having continued access to the instructional content on the Edpuzzle platform, as the tutorial content remained available for student access up until Quiz C. As Appendix K presents, two students had accessed tutorial content for at least 2 hours, and this could be the result of students re-watching instructional content to keep up-to-date with their understanding after the completion of the topic. Unfortunately, the time analytics data used in this research did not provide the opportunity to check when students accessed tutorials as it was compiled at the end of the research (see Section 3.7.3). For example, Student 18, who had decreased in their stage of understanding from Quiz A (Stage 3) to Quiz B (Stage 1), was able to increase their understanding for Quiz C (Stage 3), with a total viewing time of 2 hours. It is not known when they accumulated the 2 hours; however, it is plausible that the additional viewing time came between Quizzes B and C given the increase in understanding.

The results indicating that students in the flipped group had retained their understanding after a 3-week delay differs from previously published findings. For example, while Love et al. (2014) observed significantly greater changes in the scores of students undertaking a flipped classroom when compared to a traditional lecture-based group, they later observed these gains to disappear at the end-of-semester exam. This doctoral research found a different result. Student results were similar throughout the topic in this research, yet the flipped group later outperformed the regular group during the delayed test (Quiz C). Two suggestions could account for this difference. The first is that Love et al.'s (2014) study was on student achievement, as determined through midterm assessments and final exams, which were measured through percentage scores. While it could be expected that achievement related to understanding, without the marking schema for those assessments, it is difficult to determine the types of linear equations that the students in Love et al.'s (2014) study could solve using only percentage-based measures. The second is that the instructional flipped content in Love et al.'s (2014) study was available to students in the traditional course. This may have resulted in the diffusion of treatment effects between the flipped and traditional groups. The flipped instructional content in this research was not made available to the regular group at any stage, which was a deliberate design feature given previous research had not been strict in the control of content accessibility (e.g., Kirvan et al., 2015). The difference in access between Love et al.'s (2014) study and this research may have contributed to the difference in outcomes, with the flipped group in this research being the only students able to revisit content on demand.

6.2.2 Misconceptions and Knowledge Gap Comparisons Between Flipped and Regular Groups

The collated incidences of MKGs for Quiz C provided further insight into student understanding of solving linear equations in both the flipped and regular groups. These insights extend to students' ability to retain, develop, or eradicate previously diagnosed MKGs from Quiz B. Table 6.5 summarises Tables 4.6 and 4.7 for the number of MKGs in the flipped and regular groups in Quizzes B and C.

Table 6.5

Misconception or Knowledge Gap Frequency for the Flipped and Regular Groups: Quizzes B and C

	Flipped Group (*n* = 20)		**Regular Group (*n* = 22)**	
Misconception or Knowledge Gap	**Post Topic Quiz B Frequency**	**Delayed Test Quiz C Frequency**	**Post Topic Quiz B Frequency**	**Delayed Test Quiz C Frequency**
SE	7	4	9	8
AES	2	1	2	1
BES	0	0	2	0
RES	0	1	0	2
AF	7	8	5	10
Total	16	14	18	21

Note. SE = simplification error, AES = addition equation solution, BES = bracketless equation solution, RES = reverse equation solution, AF = algebraic fraction. Up to 20 flipped group students and 22 regular group students could be diagnosed with each MKG.

Table 6.5 shows the total frequency of MKGs for the flipped group to be less in Quiz C (14 instances) than in Quiz B (16 instances). This occurred alongside a decrease in the number of students diagnosed with MKGs, with only 10 students. Nine of these students had previously diagnosed MKGs in Quiz B, and one additional student diagnosed with an MKG following Quiz B (Table 4.6). This was in contrast to the regular group where the overall frequency of MKGs increased between Quiz B (18 instances) and Quiz C (21 instances). This occurred with the same number of students having an MKG (14 students; Table 4.7). Eleven of these students had previously diagnosed misconceptions in Quiz B, and three additional students were diagnosed with an MKG following Quiz B (Table 4.7). The change in total frequency of MKGs for students in each group was the result of changes to the distribution of diagnoses for particular types of misconceptions, each of which are discussed below.

The SE misconception was no longer the most frequent MKG, with the number of students diagnosed with the SE misconception decreasing in both the flipped (three fewer) and regular (one fewer) group on Quiz C compared with Quiz B (Table 6.5). Both groups demonstrated a similar reduction in the SE misconceptions.

The frequency of diagnosis for AES misconceptions decreased for both groups on Quiz C. Both the flipped (Students 6 and 7; Table 4.6) and regular (Students 9 and 10; Table 4.7) groups each had two students with this misconception on Quiz B, with these students no longer diagnosed with the misconception in Quiz C. However, one student in each group (Student 18 in the flipped and Student 2 in the regular) each demonstrated the AES misconception on Quiz C despite not doing so on Quiz B. Both of these students had shown this particular misconception through Quiz A; thus, it appears that both approaches produced similar outcomes for the AES misconception.

Despite both the flipped and regular groups having no students with an RES misconception on Quiz B, both groups had students diagnosed with the RES misconception on Quiz C. The flipped group had one student diagnosed with RES (Student 3; Table 4.6), and the regular group had two (Students 6 and 10; Table 4.7). The similar increase to this misconception once again highlights a somewhat equal impact for Kate's flipped and regular approaches with regard to the RES misconception.

The incidence of the BES misconception remained unchanged for the flipped group, with Quiz C continuing to show no student diagnosed with the misconception. The results were just as positive for the regular classroom group, with both students who had demonstrated the BES misconception during Quiz B no longer exhibiting that incorrect understanding. This outcome suggests that both the flipped and regular classrooms were effective in addressing the BES misconception.

The AF knowledge gap overtook the SE misconception to become the most frequent MKG for both the flipped and regular groups on Quiz C. However, there were differences in the prevalence of this knowledge gap between the groups. The flipped group increased in the incidence of AF by one student, from seven students at Quiz B to eight at Quiz C. The two students previously diagnosed with the AF knowledge gap no longer had this in Quiz C; however, five others retained it, and three others developed it between Quizzes B and C.

The regular group doubled in the number of students with the knowledge gap, from five students in Quiz B to 10 at Quiz C. Only one of the students who demonstrated this knowledge gap in Quiz B was able to correct it; four others retained their knowledge gap, and six additional students were diagnosed with it between Quiz B and Quiz C. This increased diagnosis in AF is indicative that neither approach was effective at improving understanding in response to the AF knowledge gap. Given both groups were exposed to the same instructional content, it is perhaps the instruction and not the regular or flipped approach that may account for this increase to AF.

6.3 Student Attitude: MTAS Survey Results

This section discusses the results from the five subscale measures from the MTAS survey for the flipped and regular groups, as presented in Chapter 4. A review of the statistical analysis is first presented for each subscale to compare the student attitudes before and after the linear equations topic. The qualitative aspects of these data are then discussed and compared between groups with reference to the changes in students' attitude between the three levels—high, moderate, and low—and the proportion of favourable responses for each group. This qualitative aspect allows greater insight into individual student attitude within each of the flipped and regular groups and provides an overall snapshot of student movement between attitude levels for each group. Both the quantitative and qualitative comparisons between groups contribute evidence for answering RQ3.

6.3.1 Quantitative Analysis Discussion: Comparison of MTAS Data Between Flipped and Regular Groups

The five subscales items—mathematics confidence (MC), confidence with technology (TC), attitude to learning mathematics with technology (MT), behavioural engagement (BE), and affective engagement (AE)—were statistically analysed based on students' responses to the MTAS survey as described in Section 3.8.2. The statistical analysis for each attitude subscale allowed an overall quantitative understanding of how the groups (i.e., flipped or regular) responded to each pedagogical approach.

The pre-topic MTAS survey indicated there was no statistical difference between the groups for any of the five measured subscales prior to the linear equations topic (Table 4.1). The post-topic survey, which was the same MTAS survey, confirmed there was no statistical difference for any subscale between the groups at the end of the linear equations topic (Table 4.2). These results indicate that given the attitude of the flipped group was similar to that of the students in the regular group before and after the topic, neither mode of pedagogy was statistically any more effective than the other at influencing the group's collective attitude to learning mathematics. This finding is similar to Chao et al. (2015) who observed no statistical difference in student attitudes after flipped implementation, despite noting positive perceptions through student interviews. While interviews were not conducted through this doctoral study, students were able to provide their thoughts and perceptions through responses to open-ended questions after the topic. Positive perceptions and attitudes (i.e., what could be considered affective and behavioural engagement through MTAS) were noted through these open-ended responses (see Section 6.4); however, these do not appear to have influenced the statistical measurements.

6.3.2 Qualitative Analysis Discussion: Comparison of Changes in Student Attitude Between Flipped and Regular Groups

This section describes and compares the changes that occurred in student attitude in the flipped and regular groups for each subscale. Each subscale is discussed separately by analysing the number of students in each group who self-reported a favourable response (i.e., a numerical score of 12 or above; see Section 3.8.2) and nonfavourable response. The movement of students between low, moderate, and high attitude levels between pre- and post-testing is also described to better understand the influence of the flipped approach on student attitude.

6.3.2.1 Comparison of Changes in Student Attitude: Mathematics Confidence

The mathematics confidence subscale relates to a student's perception of their ability to attain good results and their assurance that they can handle difficult situations in mathematics. Changing the way that students are presented with mathematics concepts (i.e., outside regular class) presents the potential to alter confidence levels (as their usual structure of the classroom/teacher support are disrupted). This subscale provided the opportunity to see if this occurred in this research.

Through analysing the change in students reporting favourable attitudes between pre- and post-topic surveys, Table 6.6 shows that the number of students reporting a favourable attitude in the flipped group remained unchanged (16 students). This is compared to a two-student increase in the regular group (Table 6.6).

Table 6.6

Students With Favourable Attitude (Mathematics Confidence): Pre- and Post-Survey Comparison

Group	Pre-Survey Favourable	Post-Survey Favourable
Flipped (*n* = 22)	16 students 73%	16 students 73%
Regular (*n* = 21)	12 students 57%	14 students 67%

Note. Student responses that were "moderate" or "high" level (i.e., have a score above 12) were considered as favourable.

While Table 6.6 shows that the number of students with a favourable attitude remained unchanged in the flipped group (16 students), there was considerable movement in the reported attitude levels (i.e., low, moderate, and high) for both groups. In particular, four students in the flipped group decreased in their self-reported attitude level, with two moving from high to moderate and two from moderate to low (Figure 4.2). The flipped group also had three students increase in their reported attitude, with two moving from low to moderate and one from moderate to high (Figure 4.2). In comparison, the regular group had only one student reporting a decreased attitude level, moving from high to moderate (Figure 4.3). The regular group had more students reporting an increased attitude when compared to the flipped, with two moving from low to moderate and two from moderate to high (Figure 4.3). This movement in student attitude level led to more students in the regular group reporting a high-level of mathematics confidence when compared to the flipped group, despite being equal before the topic. The change in attitude for the regular group therefore appears to appear more positive (with more increases, and fewer decreases).

Kate commented through the interviews (Section 6.5) that the flipped group's confidence was higher than what she was observing in both her regular group and previous years of teaching, reciting comments from the students motioning that algebra was easy. However, this was not evident in the mathematics confidence subscale data, which showed more students in the flipped group to decrease in their mathematics confidence compared to the regular group. This discrepancy is perhaps accounted for by the length of time between Kate discussing student comments about finding algebra easy (Interview 2) and the time students responded to the post-survey at the end of the topic (approximately 2 weeks later). The students' confidence in mathematics may have changed between those time points and thus could not be measured in the way Kate had observed in class.

6.3.2.2 Comparison of Changes in Student Attitude: Confidence With Technology

The confidence with technology subscale reflects the assurance that students have in themselves to use a range of commonly available technology, both in and outside the classroom. In both the flipped and regular groups, students had access to a MacBook computer that they used to access questions and content relating to the linear equations topic. The flipped group had a new use for this technology: utilising their MacBook technology to access the Edpuzzle platform to view and engage with their instructional content. Differences in confidence levels with technology could, therefore, be attributed to the increased reliance on Edpuzzle for instruction given the use of other aspects of technology remained constant for both groups outside this (i.e., use of MacBook to access the textbook).

With respect to student changes in confidence with technology between pre- and post-topic surveys, the data indicated a similar decrease, with both groups having two fewer students who reported a favourable attitude for confidence with technology (see Table 6.7).

Table 6.7

Students With Favourable Attitude (Confidence With Technology): Pre- and Post-Survey Comparison

Group	Pre-Survey Favourable	Post-Survey Favourable
Flipped (n = 22)	20 students 91%	18 students 82%
Regular (n = 21)	17 students 81%	15 students 71%

Note. Student responses that were "moderate" or "high" level (i.e., have a score above 12) were considered favourable.

The decrease in favourable responses in the flipped group were the result of eight students decreasing in their self-reported attitude level, with five students moving from high to moderate and three moving from moderate to low (Figure 4.5). Only one student in the flipped group increased in their attitude level, moving from low to moderate (Figure 4.5). In comparison, the regular group had only four students reporting a decreased level of attitude (two from high to moderate and two from moderate to low; Figure 4.6), with three students reporting an increased attitude (from moderate to high; Figure 4.6). Despite these larger decreases and fewer increases to reported attitude in the flipped group, the flipped group still maintained a higher number of students reporting a favourable attitude (i.e. raw number of students reporting a moderate or high attitude) for confidence with technology (Table 6.7).

6.3.2.3 Comparison of Changes in Student Attitude: Learning Mathematics With Technology

As discussed above, students from both the regular and flipped groups had access to a MacBook computer, which they used to view online work and visualise aspects of content through the online textbook. Hollowell and Duch (1991) reported significant gains in confidence about learning and performing well in mathematics after using computers as a tool during mathematics instruction. Given that both groups had access to technology when learning mathematics, it was important to ascertain if the Edpuzzle aspect contributed any further impact to student attitude to learning mathematics with technology.

When comparing the changes in reported attitude level between the flipped and regular groups, there was a notable difference in the number of students with favourable attitudes to learning mathematics with technology in the flipped group (see Table 6.8).

Table 6.8

Students With Favourable Attitude (Mathematics With Technology): Pre- and Post-Survey Comparison

Group	Pre-Survey Favourable	Post-Survey Favourable
Flipped (*n* = 22)	16 students 73%	21 students 95%
Regular (*n* = 21)	13 students 62%	13 students 62%

Note. Student responses that were "moderate" or "high" level (i.e., have a score above 12) were considered favourable.

The increase in favourable attitude for learning mathematics with technology in the flipped group was the result of substantial changes in student attitude levels. For example, Chapter 4 showed that five students increased in their attitude level, three of whom moved from a low to high (Figure 4.8), the largest increase observed in this research (two levels, where all others were one level of change). No student in the flipped group decreased a level in their attitude, and this again was the first and only instance where no regression was observed for any attitude subscale for any group. In comparison, the number of students reporting a favourable attitude for learning mathematics with technology remained unchanged for the regular group (13 students; Table 6.8). This was the result of an equal number of students increasing and decreasing in their attitude level, leaving the group in the same net position, with the majority of students reporting either a moderate or low-level attitude to learning mathematics with technology.

Although no MTAS item directly linked to the use of Edpuzzle, there was an increase in the number of students reporting a favourable response to learning mathematics with technology at the end of the topic for the flipped group, which was not observed in the regular group (Table 6.8). Given the items in this subscale included "Using computers in mathematics is worth the extra effort" (MT 2; Table 3.3) and "Mathematics is more interesting when using computers" (MT 3; Table 3.3) this could be the result of students finding more purpose in learning through the tutorials on Edpuzzle on their computer. An increased propensity for students to identify tasks as being purposeful to their learning was reported by Jensen et al. (2015) after implementing a flipped approach, and it may be that students in this research saw more purpose to the use of their technology to complete tasks for learning mathematics in a flipped classroom than they had previously done through a regular classroom.

6.3.2.4 Comparison of Changes in Student Attitude: Behavioural Engagement

Behavioural engagement examines what students do both in and out of class in order to learn and was measured through self-reported responses to four questions on the MTAS instrument.

Table 6.9 shows that the flipped group demonstrated an increase of three students with a favourable behavioural engagement attitude (20 students; Table 6.9), while the regular group remained with the same number of students reporting a favourable attitude (18 students). Increases to engagement have been cited through the literature after the introduction of the flipped classroom (e.g., Bhagat et al., 2016; Chao et al., 2015; Clark, 2015), and this observation is therefore consistent with findings in the literature.

Table 6.9

Students With Favourable Attitude (Behavioural Engagement): Pre- and Post-Survey Comparison

Group	Pre-Survey Favourable	Post-Survey Favourable
Flipped (n = 22)	17 students 77%	20 students 91%
Regular (n = 21)	18 students 86%	18 students 86%

Note. Student responses that were “moderate” or “high” level (i.e., have a score above 12) were considered favourable.

While the number of students reporting a favourable behavioural engagement remained unchanged in the regular group, the number of students with a favourable attitude in the flipped group increased. This was due to three students in the flipped group increasing from a low to moderate attitude level (Figure 4.11). This could indicate an enhanced ability for lower level attitude students to engage more with their work through a flipped classroom.

Furthermore, students' responses to the open-ended questions highlighted a prevalence for them to persist with understanding concepts through rewinding and re-watching tutorial videos (see Sections 6.4.1 and 6.4.2). Through this, students may have exhibited a sense of increased behavioural engagement. Kate's commentary through the semistructured interviews also highlighted an increased persistence by students to seek help from peers and herself, and this too could account for this increased number of students with a favourable attitude (see Section 6.5).

6.3.2.5 Comparison of Changes in Student Attitude: Affective Engagement

The affective engagement subscale assesses how students feel about or enjoy mathematics. Given the differences in the way that students could learn (or be presented with) mathematical explanations or content in both groups, this subscale should help to reveal if there was a subsequent impact on how students felt about mathematics in general.

Both the flipped and regular groups decreased by one student in the overall number of students with a favourable affective engagement attitude (Table 6.10).

Table 6.10

Students With Favourable Attitude (Affective Engagement): Pre- and Post-Survey Comparison

Group	Pre-Survey Favourable	Post-Survey Favourable
Flipped (n = 22)	18 students 82%	17 students 77%
Regular (n = 21)	14 students 67%	13 students 62%

Note. Student responses that were "moderate" or "high" level (i.e., have a score above 12) were considered favourable.

While the flipped group had more students with a favourable affective engagement on the post-survey (17 students; Table 6.10) when compared with the regular group (13 students; Table 6.10), both groups declined by only one student in favourable attitude when compared to the pre-survey. Comparison of the attitude levels for affective engagement revealed a more detailed picture. The change in three more students reporting a low-level attitude in the regular group made the low-level attitude the most frequently reported for the regular group (eight students at low-level; Figure 4.15). This was in contrast to the flipped group, where the majority of students reported a moderate-level attitude (13 students at moderate-level; Figure 4.14). This difference in attitude level could indicate a favourable position for the flipped classroom; however, it is difficult to determine the extent to which that would hold true with small numbers. However, any suggested improvements to affective engagement could be validated by the increased enjoyment indicated by the flipped group by the open-ended student responses, where students clearly articulated their enjoyment of this way of learning (Section 6.4).

6.4 Student Perceptions About the Flipped Classroom

This section explores the flipped group students' open-ended responses from their post-topic survey. Using the clusters and themes presented in Section 5.1, this section presents the analysis of student perspective and understanding, drawing links to the previously presented attitude data and the current published literature to better understand student perception of the flipped classroom and its relevant significance (RQ4).

6.4.1 Student Control of Learning

Students in the flipped classroom made regular links to the theme of being able to control their learning, through being able to pause or rewind (S1.1) or re-watch material (S1.2) alongside control when, where, and how they would access the instructional content provided in the video tutorials (S1.3). The theme of *Student Control of Learning* had three clusters formed by positive comments made by students about their experience in learning through instructional videos.

Positive student comments centred on the ability to "work at a pace which was comfortable" (S17-1) and "go at my own pace" (S4-1), which were reflective of students who appreciated the ability to control the pace of their learning (S1.1). The independence this brought was noted by students that they no longer "had to wait for others or others don't need to wait for me" (S3-3). These comments highlighted the capacity of the flipped classroom to move beyond the capability of the regular classroom. Examples and explanations could be viewed on demand and at a speed that was differentiated to, and by, the student. This theme confirmed that the capacity to review and self-pace instructional content was seen as an advantageous facet of participation in the flipped classroom, a notion that is well held in the current flipped literature (e.g., González-Gómez et al., 2016; Lo et al., 2017; Smith, 2015).

The significance of this point is relayed through Goodwin and Miller (2013), who highlighted that one of the largest shortcomings to any direct instructional-based format (i.e., the regular classroom) was the issue of pacing. In particular, they commented,

> For some students, the information may come too slowly or cover what they already know; other students may have trouble taking in information so rapidly, or they may lack the prior knowledge they need to understand the concepts presented. After a hit-or-miss lecture, teachers often assign homework, which many students perform in a private hell of frustration and confusion. (Goodwin & Miller, 2013, p. 78)

Providing students with an opportunity to decide how fast or slow they want to go when receiving explanations bridges the dilemma noted by Goodwin and Miller (2013). The added advantage of pre-recorded instruction is that it allows what would have been an initial "once-off" explanation in the classroom to become students' permanent resource to review, remember, and understand the explanations presented. The ability to pause, rewind, review, and re-cover crucially delivered information is a staple facet to the technology-enabled flipped approach, and it stands to reason through the comments made by students in this research that it enhanced the overall learning environment.

6.4.2 Student Concentration and Focus

Student *Concentration and Focus* as a theme encapsulates students' ability to concentrate and focus on content explanations when learning linear equations through video tutorials. This theme had two clusters and, unlike the previous theme, had both positive and negative student perceptions.

Cluster S2.1 shows eight students to have commented that the video tutorials had assisted them with their concentration, and this was due to watching the "videos by myself because I learn better without distractions around me" (S1-4). Given the dynamics of the regular classroom, with class sizes of up to 29 students, this highlights a facet of the flipped classroom to better support student learning. In the regular classroom, students are required to learn content in the presence of 28 other students, with 28 other potential distractions. The flipped classroom, therefore, can offer learning that is not readily available in the regular classroom, with content explanations that are free from distraction, assisting students in focusing.

By contrast, Cluster S2.2 outlines the two students who had trouble with their concentration and focus due to the content delivery through video explanations in the flipped classroom. These students mentioned that it was "easier to lose focus when at home" (S1-5) or that they were "distracted more at home" (S4-3). While only two students mentioned this loss of focus through needing to watch content at home, this highlights that the non-classroom environment of learning is not for everyone. While the majority of student comments in this theme were positive about being able to concentrate by themselves, this cluster highlights that teachers should be aware that not all external environments are conducive to learning, and thus, not all students will be receptive to watching mathematical explanations in their home environment.

6.4.3 Student Understanding

The theme of *Student Understanding* refers to the aspects of the flipped classroom that either assisted or hindered student understanding when learning to solve linear equations. This theme contained the most number of comments overall from students, suggesting students recognised the overlap that this way of learning had on their understanding.

Students commented on the ability to pause videos to assist their understanding (S3.1). Comments such as "Sometimes I was confused as to what I was writing and pausing allowed me to stop and think" (S7-2) gave a clearly defined insight that students appreciated the extra time that pausing allowed to process recently learned information. Additionally, S3.3 demonstrated the advantage of being able to review videos, with students commenting they would "keep playing" (S21-3) a video and review content "until it made sense" (S9-3). These clusters highlight that some students' understanding is better supported by the functionality that a flipped classroom can offer (i.e., pause and review). Interestingly, while Bhagat et al. (2015) attributed the ability to pause or rewind to assist in learning content of benefit to lower ability learners, it is pertinent to note that the comments made by students in this doctoral research came from a mixed spread of ability (i.e., students who had achieved Stages 0 to 4 in the solving linear equations quizzes). This serves to highlight that using video tutorials in the flipped classroom is a viable tool for differentiation for all learners, not just those with lower ability. This particular contention is supported further by Cluster S3.2, with some students highlighting the flipped classroom made learning “easier to understand” (S15-1).

This theme also highlighted the advantage of embedding formative assessment within video explanations to support their understanding (S3.5), with some students commenting that they liked how quizzes “make sure you were paying attention” (S2-3). They also recognised it as an opportunity for the teacher to explain in class the “difficulties students found in some example questions” (S17-2). The use of online questions for students to practise and check their understanding was a recommendation made through the review work of Lo et al. (2017), who incorporated this as a design principle (Principle 5; outlined in Section 3.7.1). Some students in this research emphasised the usefulness and importance of incorporating this type of assessment, with students commenting, “I liked how we had questions that we could test ourselves and if we got them wrong it’d be explained the next day” (S13-2).

However, this theme did not just represent positive perceptions of the flipped classroom. Four students highlighted that the flipped classroom did not provide them with the same level of opportunity to engage with content as would otherwise have been available in the regular classroom (S3.6 and S3.7). These students had concerns that the teacher in the flipped classroom could not go “into more depth” (S21-1) when concepts were being explained or needed to be elaborated. These students preferred the regular classroom as “if needed further examples and explanation can be given” (S2-5) to better support their understanding.

6.4.4 Features of a Flipped Classroom

The theme *Features of a Flipped Classroom* refers to comments that students made about how they viewed and interacted with specific features of the flipped classroom, with four clusters comprising this theme. This theme was important to establish the reason why students accessed features of the flipped classroom, with Cluster S4.1 indicating that students primarily paused videos to allow them the time to copy down examples and notes into their workbooks.

A negative perception arose for a group of six students through Cluster S4.2, with an indication that being unable to access immediate assistance from their teacher when they encountered difficulty with the explanations in the video was problematic. These students typically referenced their ability to raise their hand in the regular classroom during explanations to seek clarification and the fact this was missing through the flipped classroom. While this was a negative perception for these six students, it may speak to the need for these students to continue to adjust to this new learning style and a need for the teacher to set in place explicit strategies for students to recognise that they can seek assistance in subsequent lessons or through other forums (i.e., perhaps an online message board, email, or an understanding that problems can be addressed in the next lesson). This adjustment in learning style was evident in the three students from Cluster S4.4, who acknowledged and utilised the ability to follow up with questions in the next lesson after difficulties had arisen in the video. Further to this are the acknowledgements of the four students from Cluster S4.3 who recognised they had more time and opportunity through a flipped classroom to ask questions in class given their time had been freed up through watching videos at home. Balancing the perceptions of students in Cluster S4.2 with those made through S4.3 and S4.4, it becomes clear that the flipped classroom features had more positive perceptions than it did negative.

6.4.5 Student Preferences Regarding Flipped Videos

The theme *Student Preferences Regarding Flipped Videos* refers to comments that students made about their preference towards specific aspects of the flipped classroom video tutorials. These comments were separated by three clusters and typically centred on how the videos were created, along with their viewing preferences.

Given the cited increases to planning and time commitment through flipped classroom implementation (e.g., Akçayır & Akçayır, 2018; Low et al., 2017), a viable alternative could have been to source videos from the internet to save the teacher time in having to create their own. While only three students indicated they had no preference if their teacher created the video (Cluster S5.3), there were many more students who would take issue with watching videos not created by their teacher. Cluster S5.1, *Preference for their teacher to have created the flipped video tutorials*, represented the views of nine students who indicated that they would prefer to watch a flipped tutorial created by their teacher rather than something generic from the internet. These students cited their reasons as having an established familiarity with their teacher's way of presenting concepts and that watching someone else could confuse them further. Additionally, there were concerns from some students that videos sourced from the internet could not be trusted as much as their teacher. These are important points for teachers to be aware of if they are looking to trade off the time commitment in creating their own videos, as they may be introducing some resistance in the students through their ability to trust or understand the teaching approach. Indeed, Kuiper et al. (2015) made this point, referring to the differing notation in statistics courses making it difficult to rely on the videos created by other teachers. This doctoral research highlights that many students do indeed prefer their own teacher's explanations in video tutorials.

6.4.6 Student Preference for Learning

The flipped classroom student responses indicating which approach to learning they preferred to learn from in the future (i.e., regular or flipped) produced a clear preference for the flipped classroom (see Figure 5.1), with 17 students (77% of the class) nominating the flipped approach. This majority consensus towards the flipped approach is in contrast to the conclusion from Grypp and Luebeck's (2015) action research study. Grypp and Luebeck (2015) investigated the impact of the flipped classroom approach when teaching calculus to 21 high school students over a 3-week period. The authors concluded, "Most students said that they would recommend flipped instruction, but there was no overwhelming consensus about which mode of instruction they preferred" (p. 191). Given the same time duration in intervention between this present doctoral research and Grypp and Luebeck's (2015) research, this finding highlights that more remains to be understood about the reasons behind student preference in approach. It could perhaps be that students see more worth in the approach for one topic (i.e., linear equations, as in this research) and not so much for others (i.e., calculus, as in Grypp and Luebeck's research). While other research has reported favourable responses to the flipped classroom (e.g., Clark, 2015), and the preference for one way of learning over the other, the reasons for this may well be topic dependent. These decisions also hinge on the use of specific pre-class and in-class activities; as demonstrated through the discussion in Section 2.5, these can alter the experiences of students in each class (e.g., Bhagat et al., 2016; Jensen et al., 2015). This doctoral research shows that in the absence of change to in-class activities, the flipped approach can still elicit a favourable response from students.

6.5 Teacher Experience and Perspective

This section discusses the findings from the three semistructured interviews with the teacher participant, Kate, highlighting the prevalent clusters from each of the six themes presented in Section 5.2 to establish the teacher participant's experiences through flipped classroom planning and implementation. These experiences are analysed in reference to the previously presented literature to understand a classroom teacher's experiences and perspectives when implementing the flipped classroom for the first time.

6.5.1 Requirements for the Flipped Classroom

The teacher theme *Requirements for the Flipped Classroom* categorised the critical requirements for flipped classroom implementation based Kate's experiences and perspectives. The two clusters in this theme provided insight for teachers deciding to implement a flipped classroom.

Cluster T1.1 contained Kate's comments in the three interviews about the need to give clear expectations to students concerning their participation in the flipped classroom. There was an initial acknowledgement at the planning stage (Interview 1) that clear expectations would need to be given for pre-class and in-class activities to avoid students wasting time. Kate explicitly communicated these expectations to students, which the literature highlights as crucial for student participation (Lo et al., 2017). It would seem that Kate's clear articulation of when to watch video tutorials (before the next lesson) and what to do once they had been watched (write summary notes) provided a sufficient opportunity for students to feel engaged with the flipped classroom. This engagement is evidenced through Kate's observations of an effective classroom environment but also the results of preference for learning mentioned in Section 6.4.6 and the acknowledgement of the approach's efficacy made through the student comments in Section 6.4. It is however pertinent to note that a revisit of these expectations was required by Kate to ensure continual adherence by all students (see Section 5.2.1).

The need for teacher technology competence was also highlighted as necessary for teachers in this theme (T1.2). There were 11 references to adjustments in getting used to using new technology made over the three interviews. Through this cluster, an understanding of the increased teacher workload cited by others began to come to the fore, as Kate had several difficulties in flipped classroom planning and implementation through getting used to the new technology this required. However, this is in line with the time commitment documented through the literature, with McGivney-Burelle and Xue (2013) acknowledging, "Those new to flipping should expect many technology glitches especially when creating the first few videos" (p. 484). In Interview 3, Kate acknowledged her competency of technology had reached a point where it was no longer an issue, and so this commitment was something that had only taken approximately 2 weeks to gain sufficient competence in.

6.5.2 Understanding the Process

Understanding the Process highlights the processes that a teacher should be aware of when undertaking flipped classroom implementation. Three clusters formed this theme, which had an underlying focus on planning.

Cluster T2.1 directly references the additional time commitments of the flipped classroom. Through this cluster, an understanding of the increased teacher workload cited by others began to come to the fore. Talbert (2015) described a scenario ratio of "roughly a 6:1 ratio in time spent scripting and producing each video to the running time of the video" (p. 624). Kate reiterated this scenario when discussing that her first approximate 10-minute video took 2 hours to create. The issues surrounding this extended time were partly due to the need for technology competence, as acknowledged through the previous section; however, the preparation of notes and sequencing for each lesson also required significantly more time than she had otherwise spent in her regular lesson planning (see Appendix I for planning notes). There was, however, the acknowledgement that this additional time was worth it, as Kate could see both an immediate impact of the videos and a potential impact (discussed next in Section 6.5.3). These acknowledgements were similar to those highlighted by McGivney-Burelle and Xue (2013) who claimed, "Once a polished set of videos and course materials are created the preparation time will be significantly reduced" (p. 484).

Given the amount of time spent creating video tutorials, Cluster T2.2 provided insight on the time that could be saved through accepting that teacher-created videos, at least in their initial implementation, do not need to be perfect. A significant amount of Kate's time was spent trying to eradicate "ums" and "ahs" in addition to minor errors (i.e., incorrect annotations that could have been corrected in the video) that forced Kate to start the video again rather than adjust or acknowledge the mistake and move on. After creating "around five lessons" (T1_12), Kate began to accept these imperfections as part of the process, and students' feedback about video quality reinforced that the videos were acceptable.

Just as was the case within the student clusters, the usefulness of the online quiz questions was also highlighted through Cluster T2.3. The ability to view student progress in video tutorials through use of quiz questions, while producing no surprises to Kate, provided an opportunity to step students through common incorrect concepts as a focal point for the next lesson. Research (e.g., Bhagat et al., 2016; Love et al., 2014) has demonstrated the power in being able to target specific groups of learners based on the progress of students in pre-class activities. The questions embedded in Edpuzzle tutorials in this doctoral research were useful in achieving this same outcome; however, Kate acknowledged that she did not adapt her teaching approach based on the student responses to the questions. This could be of more use to someone with less experience in the classroom (i.e., a beginning teacher), who may be unaware of what the broader classroom issues may be in understanding content.

6.5.3 Key Perceived Outcomes (Resources)

The theme of *Key Perceived Outcomes (Resources)* detailed the reusable nature of created resources.

The previous section elaborated the time burden, both from Kate's perspective and that documented in the literature, that a flipped classroom introduces through creating video tutorials. However, there was also an acknowledgement that once these videos had been created, there would be a reduction in demand for future planning time. Furthermore, Kate added the perspective of having to teach multiple classes—in that, for a teacher, it can be "draining" if you have multiple classes at the same year level to deliver the same instruction over and over again, sometimes within the same day. The video tutorials, therefore, alleviate the need for the teacher to continually "repeat" lesson content from one group to another and instead allow a focus on the individual needs of the class. Furthermore, the reusable nature of the videos was extrapolated by Kate to not only extend to a reduction in planning for future years but also provide an opportunity for absent students to catch up on missed content, a facet she observed during the flipped classroom implementation in this research.

6.5.4 Key Perceived Outcomes (Classroom Engagement)

The theme *Key Perceived Outcomes (Classroom Engagement)* detailed the aspects of student classroom engagement, from Kate's perspective, that were impacted through flipped classroom implementation. Two clusters formed this theme, focusing on what was observed in class with regard to how students behaved and interacted with each other during scheduled class time.

After implementing the flipped classroom, semistructured Interviews 2 and 3 provided a clear insight into what Kate was observing during the in-class components of both the flipped and regular classrooms. Cluster T4.1 highlighted an increased engagement in the flipped classroom during the in-class component, with students more engaged in working on their questions and showing less behavioural issues than her regular classroom. Kate attributed the disparity in engagement and behaviour in the two classes to the fact that the regular classroom students were "tired of it all" (T3_10) after hearing a lengthy in-class explanation and then needing to proceed with in-class activities. The flipped classroom offered a break to this format, with students being able to view the same explanation at their own pace and time before class. The impact of this was fewer behavioural disruptions and more active participation in the classroom, an insight acknowledged through Clark's (2015) flipped classroom action research study. Again, it is pertinent to highlight that the heightened engagement was not the result of altering the in-class activities to other forms of instruction (i.e., active-based learning), as has been reported through other studies (e.g., Jensen et al., 2015).

Alongside heightened engagement, Kate found an increased propensity for students to be "helping each other more". The increased opportunity for students to interact and collaborate in the flipped classroom (Cluster T4.2) has been noted to assist enhanced learning through structured peer-based learning, with Lo et al. (2017) highlighting 33 studies to have reported benefits due to peer-assisted learning through their review of the flipped classroom literature in mathematics. While Kate did not build peer-assisted learning explicitly into the structure of her lessons, her observations support the notion that the flipped classroom is conducive to peer-based learning and this occurs without the requirement for planning.

6.5.5 Key Perceived Outcomes (Teacher Specific)

Two clusters relating specifically to the teacher formed the *Key Perceived Outcomes (Teacher Specific)* theme. Most prevalent through this theme were the notions of both increased support afforded to students from the teacher and reduced teacher stress in the flipped classroom.

As cited by other research (e.g., Bhagat et al., 2016; Clark, 2015; Strayer et al., 2015), the flipped classroom provided an ability to further differentiate work for students in the class given time was freed up through the removal of initial in-class direct instructional components. In this research, Kate found this to be the case, with Cluster T5.1 demonstrating an increased ability for her to determine her students' strengths and weaknesses through the flipped approach and an increased capacity for her to support them through their learning. This was largely due to students' ability to complete most of their work in class as opposed to at home. This situation did not hold true for her regular classroom, where Kate found it difficult to know where students were with their understanding "because they are doing their work at home" (T2_11).

Kate also noted she felt substantially less stress when entering the flipped classroom (Cluster T5.2). This feeling was primarily due to the decreased time constraint of moving through a given amount of content in a limited amount of time during the in-class component. Kate mentioned several ongoing struggles with both time and being able to maintain student engagement in her regular classroom, both of which were not apparent in her flipped classroom. This facet to the flipped classroom adds further to the discussion relating to time provided in Section 6.5.2; while teachers will observe an increase in their usual planning time before the unit, a potential benefit can follow in the reduction of time stress during the delivery unit, which can be a worthwhile trade-off for teachers who are feeling the struggle for time in the initial planning and implementation of the flipped classroom.

6.5.6 Key Perceived Outcomes (Learner Specific)

While the previous theme focused on the teacher, this theme centred on the outcomes likely to result for students through flipped classroom implementation. Kate's perspectives in this theme were largely reflective of those mentioned through the student clusters. However, this theme also furthered insight into some of the previously mentioned teacher clusters and themes and offered potential explanations for the advantages described in the preceding teacher comments.

The largest cluster in this theme (T6.1, 13 paraphrased comments) provides explanations for the advantages as outlined through the previous two sections, with more time availed to students for working on questions during the in-class lessons. Kate described the "big difference" students in the flipped group had to complete their work, with 80% of their lesson time used to complete questions from the textbook, in comparison to just 20% of time for the regular group (T2_12). This large disparity in time is one of the primary contributions to Kate feeling as though she had more time to support her students (T5.1), and to engage with their classwork (T4.1) and each other (T4.2).

This additional time for interaction in the flipped classroom lends itself to the second cluster of this theme, Cluster T6.2, with Kate's belief that the flipped classroom enhanced the ability to support low-achieving students. Kate highlighted this to be the result of both the ability for low-achieving students to control the pace of their content (also outlined in students' perspectives through the theme *Control of Learning*) and the subsequent increased time she could spend with these students in the classroom assisting them. Bhagat et al. (2016) highlighted that low-achieving students in mathematics would benefit the most from the flipped classroom; however, they demonstrated this through targeted interventions during the in-class activities. In Kate's example, these students availed themselves of this help without the need for a separate intervention group.

Chapter 7.

Conclusions and Implications

This chapter focuses on how this research addressed the research questions as presented in Chapter 1 of this thesis. These answers are later explored in terms of practical implications that the flipped classroom can offer in a secondary mathematics classroom. The relevant links are then made to literature to position the significance of the contribution of this research. The research limitations and recommendations for both School A and other schools are then acknowledged to contextualise the contribution of this research.

7.1 Aim of Research

This research compared the impact of two teaching approaches (flipped vs a teacher's regular approach) in the topic of solving linear equations through a case study approach in two separate Year 9 mathematics classes (flipped and regular) in a Victorian co-educational secondary school.

The impact of the flipped classroom was measured through four primary aspects:

- Student understanding of solving linear equations (pre, post, and delayed);
- Student attitude;
- Student experience and perspective of learning through a flipped classroom;
- Teacher experience and perspective of implementing a flipped classroom.

The aim of the research was met through both a qualitative and quantitative analysis, with the impact for each of the four aspects outlined by response to each research question in the Sections 7.2 through to 7.6.

7.2 Student Understanding of Solving Linear Equations (Research Question 1)

RQ1, “What understanding do students in a flipped and regular group demonstrate when solving linear equations?” was answered by the following three subquestions.

7.2.1 RQ1a: What Understanding Is Demonstrated in Each Group Before the Linear Equations Topic?

The majority of students in both the flipped and regular groups were diagnosed with a Developing or lower level of understanding of solving linear equations before commencing the linear equations topic. That is, they were able to solve the types of equations that are easy to solve through guess-and-check methods or solve equations that require less formal methods such as backtracking. Such a high percentage of students in this lower level bracket for both groups was not surprising, as most of the curriculum that students engage with before Year 9 at School A involves them understanding how to solve linear equations with systematic methods such as backtracking. This previous understanding of solving, therefore, does not rely on the use of more formal methods such as transposing or performing the same operation on both sides. No student in either group demonstrated a Complete (Stage 4) understanding before the topic. This level of understanding for both groups was reflective of an inability to employ more formal methods of solving and considered to be grounded in arithmetical thinking.

7.2.2 RQ1b: What Understanding Is Demonstrated in Each Group Directly After the Linear Equations Topic?

The number of students diagnosed with a Developing or lower level of understanding was reduced in both the flipped (three students) and regular (six students) groups directly after the linear equations topic. The majority of students in both groups demonstrated a Complex or Complete level of understanding after the linear equations topic. The increased understanding for both groups is representative of a shift in students moving from arithmetical language to algebraic language. This is indicative of an increased capacity to apply formal methods to solve non-arithmetical equations with students, with more students able to solve equations in the form $ax + b = cx + d$ and $ax - b = cx - d$.

7.2.3 RQ1c: What Similarities or Differences in Understanding Exist Between Each Group Before and Directly After the Topic?

Both the flipped and regular groups demonstrated an overall reduction in the number of misconceptions directly after the topic. This involved a similar reduction in the number of students diagnosed with SE, AES, and RES misconceptions for both the flipped and regular groups, suggesting a comparable effectiveness for both teaching approaches in addressing these types of misconceptions.

The AF knowledge gap experienced an increase in frequency for both groups between pre- and post-topic testing. Given that both groups experienced an increase in the diagnosis of this knowledge gap, and that both groups had the same explanations and examples, it is likely to be the result of the examples used by the teacher rather than whether the students were in the flipped or regular group.

One difference emerged directly after the topic with the misconception data, with the flipped group showing a heightened ability to address BES misconceptions in comparison with the regular classroom. This was evident through a seven-student reduction for BES in the flipped group, leaving no student with the misconception, a reduction that was not observed in the regular group.

Overall, the results from the pre- and post-topic stage of understanding data indicated that there were no substantial differences to the changes in student understanding between the flipped and regular groups at the completion of the linear equations topic. Despite a demonstrated increased capacity for the flipped classroom to address BES misconceptions, both teaching methods resulted in a similar development of student understanding for solving linear equations. A possible reason for the reduction in BES misconceptions in the flipped classroom may be due to students in the flipped classroom having the capacity to continually review the teacher explanations, which may have led to better consolidation. The student themes, Student Control of Learning and Student Understanding highlighted that students did find the capacity to review material as advantageous, so this may be a possible reason for increased success in overcoming the BES misconception.

7.3 Student Understanding: Delayed Testing (Research Question 2)

RQ2, "What similarities or differences in understanding exist between each group directly after the topic and after 3 weeks?" was answered through the comparison of differences in understanding on Quiz B and Quiz C for both groups.

The flipped group maintained the same number of students with a Developing or lower understanding (three students). Furthermore, the inability for two of these three students to progress was hypothesised to be due to not accessing instructional videos provided by their teacher. In contrast, the regular group increased in the number of students diagnosed with a Developing or lower level of understanding (from six students at Quiz B to nine students at Quiz C).

The regular group experienced more students decreasing from their Quiz B diagnosed stage of understanding. While the flipped group had only three students who decreased by one stage of understanding from Quiz B, the regular group had eight students who decreased at least one stage of understanding. Moreover, of these eight students, six decreased one stage, one decreased two stages, and another decreased three stages. Therefore, not only did the regular group observe more student regression, it also experienced it to a greater extent than the flipped group.

Of 20 flipped group students, 17 (85% of the group) demonstrated a Complex or Complete understanding three weeks after the topic. This was the same number of students demonstrating this level of understanding at Quiz B, representing a high retention of Complex and Complete understanding in the flipped group. This suggested that the flipped approach results in students retaining their understanding of solving linear equations beyond the teaching, which was not evident in the regular approach. In the regular group, of 22 students, 13 demonstrated a Complex or Complete understanding on Quiz C compared to Quiz B (59% of the group). This was three students fewer than Quiz B and, in combination with the larger decreases observed to stages of understanding in the regular group, is representative of reduced retention of understanding in the regular group when compared to the flipped. Furthermore, the number of students diagnosed with an MKG and the incidence of diagnosis (i.e., the number of MKGs per student) decreased for the flipped group after 3 weeks. This suggests students were able to continue to address their misconceptions outside the usual timeframe of the topic. In contrasting, while the number of students diagnosed with an MKG in the regular group remained the same, the incidence of diagnosed MKGs increased. This suggests that students in the regular group were not able to retain their understanding of dealing with MKGs as well as those students in the flipped.

Overall, the lower prevalence of MKG diagnoses in the flipped group, alongside the higher retention of students with a Complete or Complex understanding, indicates an enhanced retention of understanding for students in the flipped group when compared to students in the regular group.

7.4 Student Attitude (Research Question 3)

RQ3, "Does a flipped approach influence students' self-reported attitude to mathematics any differently to a regular approach?" was answered by the three subquestions below.

7.4.1 RQ3a: What Are the Student Attitudes to Mathematics for the Flipped and Regular Groups Before the Linear Equations Topic?

Statistical analysis of the student attitude data demonstrated no significant differences between the flipped and regular groups for any of the five subscales (MC, TC, MT, BE, and AE) before the linear equations topic. This suggests that the groups' attitudes to mathematics were the same before the linear equations topic. The mean score for each of the five subscales for each group indicated a favourable attitude, suggestive of positive student attitudes before the topic.

7.4.2 RQ3b: What Are the Student Attitudes to Mathematics for the Flipped and Regular Groups After the Linear Equations Topic?

Statistical analysis of the student attitude data demonstrated no significant differences between the flipped and regular groups for any of the five subscales measured after the linear equations topic. This suggests that the groups' attitudes to mathematics were the same for the flipped and regular groups after the linear equations topic. Again, the mean score for each of the five measured subscales continued to indicate a favourable attitude, suggestive of positive student attitudes after the topic.

7.4.3 RQ3c: What Similarities or Differences Exist Between Each Group Before and Directly After the Topic?

Despite no statistical differences to the groups' attitudes before or after the linear equations topic, a qualitative analysis of the students' attitude levels showed a small difference between attitude levels for the flipped and regular groups for each subscale.

The flipped group experienced more increases to individual student behavioural engagement, indicating a higher commitment to working through assigned work in their class. Furthermore, the flipped group experienced a heightened level of affective engagement, indicating an enhanced ability for the flipped group to enjoy their mathematics. Attitude to learning mathematics with technology had the largest change in attitude for all groups, with the flipped group demonstrating more positive increases in attitude levels for using technology to learn mathematics. These increases to attitude levels on the three subscales were validated by student preference for learning, with a majority of students (77%) preferring to learn through a flipped classroom pedagogy.

Contrastingly, students appeared less confident in their use of technology in the flipped group when compared to the regular group, and this could be due to the enhanced reliance on competence for technology in the flipped classroom. The students in the flipped group were required to use more technology to access their teacher instructions, and this involved reliance on the Edpuzzle platform, which new to technology for students. This reliance could have contributed to reducing their reported confidence in using technology. Furthermore, the students in the regular group reported more increases to their level of mathematics confidence. This was despite comparable understanding between the flipped and regular groups at Quiz B and the teacher's observations of increased confidence for students in the flipped group.

Overall, from a statistical standpoint, the flipped approach did not appear to influence students' self-reported attitudes any differently to the regular approach, with the mean score of both groups demonstrating favourable attitudes before and after the topic. The individual students' changes observed within each group did highlight more self-reported increases to higher levels of attitude for the flipped group for some subscales (i.e., AE, BE, and MT) but less increases for others (i.e., TC and MC) when compared to the regular group. A larger sample size in future may assist to determine whether these changes are significant.

7.5 Student Experience In and Perspective of the Flipped Classroom (Research Question 4)

RQ4 was "What are the student experiences and perspectives of the flipped classroom after utilising this approach to learn linear equations?"

The flipped classroom students had an overwhelmingly positive response to the flipped classroom given that 17 students (or 77% of the class) nominated they would prefer to learn in a flipped classroom rather than in a regular classroom. Students were positive about the ability to control their learning in a flipped classroom, with students favouring the flipped classroom's ability to pace their learning, pause or rewind, and review videos at their discretion. Students made several comments about the capacity of the flipped classroom to better their learning and understanding of concepts through the ability to review instructional videos. Students enjoyed viewing the video content and indicated they would prefer videos created by their own classroom teacher (as was the case in this research), as it provided them with a sense of trust of what was being explained.

However, it was not a universally positive experience for all students. Some students experienced difficulty in the transition to the flipped classroom, highlighting an inability to immediately gain clarification from the teacher when watching video explanations. These six students were more accustomed to being able to raise their hand in class when they did not understand a concept and thus attributed the inability for them to do this as a flaw of the flipped classroom.

Overall, most student experiences in and perspectives of the flipped classroom were positive. Several advantages of the flipped approach were highlighted by students (e.g., ability to self-pace, review content on demand, access help in class), with the majority of students having an overall preference to continue to learn through a flipped classroom.

7.6 Teacher Experiences and Perspectives (Research Question 5)

RQ5, "What are the teacher experiences and perspectives of implementing a flipped learning approach for the first time?" was answered by the following three subquestions.

7.6.1 RQ5a: What Requirements Exist for a Teacher to Implement a Flipped Classroom?

The experiences and perspectives of the teacher were first considered in terms of the requirements that were necessary for flipped classroom implementation. Most pertinent to the requirements for implementing a flipped classroom is that students required clear and explicit instructions to achieve appropriate participation with this new way of learning. It was also not enough to provide these expectations once; rather, students' appropriate participation (i.e., watching the videos prior to class) required initial monitoring and a subsequent follow-up on expectations in subsequent lessons to ensure students understood and adhered to the process for learning in a flipped classroom.

A substantial requirement for flipped classroom implementation was the need for the teacher to build competence with technology to create video tutorials. This requirement demanded a substantial investment of time in the initial stages of planning and preparing flipped lessons, with this contributing to an overall increase to the teacher's planning and preparation time. The teacher cited a ratio of 12:1 in terms of minutes spent planning or producing a video to the running time of the video in the initial implementation. This planning and production time gradually decreased as the teacher became more competent with technology.

7.6.2 RQ5b: What Are the Key Perceived Outcomes in Implementing a Flipped Classroom When Teaching Students to Solve Linear Equations?

A facet of the flipped classroom is being able to reuse videos, and the teacher participant's experience highlighted the multiple ways this occurred in her classroom. Reduced reliance on the teacher needing to "repeat concepts" through the class left the teacher feeling "less drained" at the end of each lesson as students were able to access content explanations independently. The transfer of content instruction to a pre-class activity in the flipped classroom led to a notable reduction in stress for the teacher in the classroom setting, with a decreased sense of pressure of having to "rush through" content in the face-to-face classroom. This outcome can be thought of as a suitable trade-off for the initial time spent in the start-up planning. Additionally, there were multiple opportunities for the teacher to reuse videos for students who had missed class due to school absences, and this was again seen as advantageous.

The heightened engagement for the flipped group was a notable difference for the teacher, with students in the flipped classroom exhibiting fewer behavioural disruptions and more focus on assigned tasks when compared to both her regular group and the same students in the flipped group before initiating the flipped classroom. The teacher participant noted a more "active" work environment in the class. The teacher cited 80% of class time could be utilised for students to work through questions in the flipped classroom in comparison to just 20% of class time in the regular classroom, so there was more time to work with and observe students as they solved questions. Alongside was a more collaborative classroom dynamic, with students helping each other more during class. These facets, in turn, allowed the teacher to observe student progression in understanding much better than she otherwise could in the regular classroom. Subsequently, this provided more opportunity for the teacher to support students in the face-to-face classroom.

7.6.3 RQ5c: What Recommendations Can Be Given to Teachers in the Transition to a Flipped Classroom?

Clear from the discussion with the teacher was the acknowledgement that the start-up time to plan a topic of work using the flipped classroom was substantially more than her regular approach. However, this increase in time declined with experience and growing competence in using technology. Thus, perseverance through this initial start-up investment in time is required. Barriers such as trying to attain perfection in videos further contributed to increased planning time; however, after accepting less-than-perfect videos, frustration and planning time decreased (to roughly 1:1 video production to running time), without decline to student feedback about the usefulness of the videos.

Embedding formative assessment questions assisted in planning future lessons appropriately, and this should be incorporated into all videos to assist in maximising flipped classroom potential. The ability to determine if a student had viewed the video and the duration of viewing time also assisted with ensuring engagement and participation in the flipped classroom, and so tools that enable this to be monitored are ideal.

7.7 Summarising the Impact of the Flipped Classroom in This Research

The response to the five research questions presented in the above sections provides a number of key learnings on the impact of the flipped classroom, which are integrated below to position the overall impact of the flipped classroom.

The change in student understanding for both groups was the same directly after the linear equations topic, suggesting both approaches were equally effective. When these groups' similar results were considered with regard to the increased time commitments required for the teacher to plan and prepare flipped videos, the efficacy of the flipped approach could be called to question.

However, the benefits of the flipped classroom became more apparent as time progressed. The delayed assessment revealed a greater retention of Complex and Complete understanding for students in the flipped group and fewer decreases to stages of understanding when compared to students in the regular group. This highlights the impact of the flipped classroom to be longer lasting, suggesting it may be worth the additional effort in teacher preparation time. Furthermore, the teacher's insight indicated that as time progressed, the flipped classroom became less cumbersome to implement; what started out as a time commitment of 12:1 (production time to video duration) eventually decreased to 1:1 after becoming comfortable with the technology. This suggests that planning commitments required are not long lasting, and the biggest hurdle to implementation is the initial time commitment required for start-up. When considered in combination with the reduced stress the teacher felt on entering a face-to-face flipped lesson, the view of flipped classroom implementation may further be considered worth the initial investment.

The changes between individual students' attitude levels for learning mathematics with technology in the flipped group highlighted that students may find more purposeful engagement in learning mathematics with technology in a flipped classroom. Furthermore, the number of students increasing (and fewer decreasing) their reported attitude level for behavioural engagement and affective engagement in the flipped classroom when compared to the regular, suggests that some students may find more enjoyment and engagement towards learning mathematics through a flipped classroom. These particular facets were validated through Kate's observations, who felt the flipped students were more readily engaged with their class work when compared to her regular group. This increased work in the class for the flipped group also availed the teacher more opportunities to monitor student progress and promoted a greater amount of peer collaboration in her class.

The overwhelming student preference for learning through a flipped classroom instead of a regular classroom further highlights that this is an approach worthy of teacher consideration and implementation. The notable increases to student confidence that the teacher observed in class, alongside most students' positive comments in reference to features of the flipped classroom (i.e., ability to pace learning to assist understanding), further validate this as a worthwhile impactful approach.

Given the flipped approach in this research was at the least equal and in the longer term more effective than the teacher's regular approach, this research demonstrates there is little detriment for teachers to trial the flipped classroom with their students. It also demonstrates that competence in the approach can be achieved by teachers over a matter of weeks, with the benefits of this investment being longer lasting (i.e., reusable videos, further opportunities to work with students in class, and catering to multiple modes of learning).

7.8 Limitations and Considerations

There are several limitations to this doctoral research. This section outlines these limitations while acknowledging the potential considerations for future research in the flipped classroom based on these limitations.

7.8.1 Sample Size (Students)

Large-scale generalisations from this research are not possible due to the limited number of students within the sample. Two Year 9 classes of students participated in this research; however, after accounting for students in each group providing consent to participate and fulfilling the criteria as discussed in Section 3.8, the sample size for each group was lower than the total class size and in both cases fewer than 24. This limited the statistical analysis of attitude to only being able to detect large differences between the experimental and control groups. Given no large differences were apparent, the qualitative aspect of this research still allowed detailed descriptive analysis between individual student movements to be described through this research. Given that the qualitative aspect of this study revealed some interesting movements between groups of students in some attitude subscales, it would be worthwhile to determine if increasing the sample size allows significance to be detected for such differences between groups. This is a particularly pertinent point given that the differences observed in attitude changes would likely be small (i.e., a change from *strongly agree* to *agree* is a relatively significant change in mindset however would only decrease a student's overall self-reported response by 1 point); hence, it may not be large enough to be detected through a small sample size.

Future research that incorporates an increase to sample size (i.e., multiple classes or multiple schools) should continue to pay careful attention to controlling for extraneous variables, including access to technology for students and ensuring the constant of the same teacher between groups being compared. Important controls should also be set for in-class and pre-class activities to ensure appropriate comparisons can be made with the larger sample size.

7.8.2 Sample Size (Teacher)

This research involved one teacher participant with over 10 years' classroom experience. The results of the flipped classroom implementation with teachers who have less classroom experience may play a role in influencing the overall impact of the flipped classroom. Future research could consider assessing the impact of flipped classroom implementation with multiple teachers at different career stages to determine if this plays an influencing role in the efficacy of the approach.

7.8.3 Access to Technology

The 1:1 MacBook environment in School A would have provided an inherent familiarity and reliance on the use of technology in student learning when compared with schools that may not have widely accessible technology. The increased prevalence and familiarity with technology could, therefore, have played a role in students' favourable experiences of the flipped classroom given there were less initial barriers to potentially overcome in the integration of technology for learning. For example, barriers described through research with relation to students having access to technology in the flipped classroom (e.g., Akçayır & Akçayır, 2018; Lo et al., 2017) were not an issue in this study due to readily available technology.

7.8.4 Duration of Intervention

The total time duration of this research equates to slightly less than one school term, and in that timeframe, students' favourable responses could be due to the novelty of the flipped approach. Longer duration research (e.g., Guerrero et al., 2015; one semester) noted that after "the novelty of the videos wore off, fatigue and boredom with the same instructional approach day after day become a factor" (p. 827). There is the possibility that extending the timeframe of the flipped approach could begin to manifest these same comments from the students in this research, and the shorter duration of this present study did not allow that possibility to be tested.

7.8.5 School Support

The teacher participant in this research was supported by School A, through attending professional learning workshops in relation to flipped classroom implementation. Replication of results in this research may be difficult without the support of the school given the teacher in this research still found difficulty in implementation (i.e., time, technology, and the need to revisit student expectations) even with this support.

7.9 Practical Implications of This Research

This section outlines the practical implications for students undertaking a flipped classroom approach. It also highlights the practical implications for teachers looking to implement a flipped classroom approach for the first time. Relevant educational institutions should consider these implications in determining if the flipped classroom pedagogy is a worthwhile endeavour for their teachers and students.

7.9.1 Practical Implications: Student Perspectives

The student data revealed that while students favoured the flipped classroom approach to learning, this was not unanimous. It is therefore essential to consider that the flipped classroom is a suitable tool for differentiation, which can appeal to a broad range of learners; however, it may not be an appropriate substitute for a teacher's current teaching approach for all learners.

Furthermore, given the issues observed through some students managing the differences in the flipped classroom (i.e., inability to ask questions immediately), it is essential to ensure appropriate and explicit information is communicated and adhered to by students to ensure an effective and productive transition to the flipped classroom. Lo et al. (2017) acknowledged the teacher's need to manage the transition to the flipped classroom, and this research shows that a continual revisiting of expectations is required by the classroom teacher. Additionally, given the comments made by students about their inability to seek immediate clarification, this research highlights a need for teachers to continually probe what is working and what could be improved so that students who feel unsupported can be adequately transitioned and supported.

Additionally, students of any technology-enabled flipped classroom environment are faced with technological demands. Issues of technology acting as a barrier to student learning is cited in the literature (e.g., Chen et al., 2014), and students from other schools looking to utilise this as an approach should consider the barriers that were not present in this study, which may be in their environment. For example, the challenge of inequality of technology accessibility for viewing video tutorials acknowledged by research (e.g., Akçayır & Akçayır, 2018) was not a challenge for students in this study due to the 1:1 laptop environment.

The flipped paradigm of instruction in this research allowed increased time for students to work on practice questions in class (four times greater than that of the regular group). This was coupled with enhanced interactions between peers and their teacher during the in-class time. The majority of students also held favourable perceptions of the flipped classroom, preferring to learn through this style for future units of work. Schools looking to utilise the flipped classroom should observe caution, however, from research that has identified a novelty effect to wear off over a semester (e.g., Guerrero et al., 2015).

7.9.2 Practical Implications: Teacher Perspectives

This study demonstrates the positive perceptions, experiences, and outcomes that can result following a teacher's first-time implementation of a flipped classroom. It highlights that the transfer of a small amount of direct instruction to a pre-class activity (often less than 10 minutes) provides substantially more time in class to observe and support student learning. However, the teacher's perspectives also reinforce what is prevalent in the literature—that the flipped classroom involves a significant investment in planning time.

It should also be acknowledged that the teacher participant volunteered to take part in this study and was made explicitly aware of the additional time investment it would likely involve. Furthermore, they were supported initially through the professional learning workshops in School A (see Section 3.3) to better understand the effective flipped classroom implementation before having to plan for it. This is pertinent to acknowledge, as Anderson and Brennan (2015) provided the example of a teacher who was uncomfortable with the format of a flipped classroom and, despite the teacher's best efforts at implementation, the students ultimately performed poorly. The teacher's willingness to trial a new approach, and the support networks in place at the school, should not be overlooked in their capacity to influence a successful flipped classroom implementation.

While this research shows the potential of a flipped classroom to deliver direct instruction as a pre-class component, this all hinges on the teacher's ability to utilise technology effectively. The TPACK framework (as discussed in Section 1.4) acknowledges the complexities involved for a teacher in managing their CK and pedagogy while appropriately adopting and utilising technology. Barriers arising from a teacher's technological competency when flipping lessons is highlighted in the literature (e.g., Akçayır & Akçayır, 2018) and, as evidenced through this research, it is important to understand there will be a substantial learning curve and time commitment required to be overcome to gain the sufficient technological competency required for a technology-enabled flipped classroom.

This research also demonstrates that students are at no detriment when the teacher is prepared to implement a flipped learning approach for the first time, and at the least, students can maintain a similar level of understanding that they otherwise would have through their teacher's regular approach (as observed between the pre- and post-topic testing). Furthermore, the experience of the teacher participant in this study (10+ years) led to her anticipating much of what the students would have difficulty in understanding, and thus, through the interviews, she acknowledged that she did not need to adjust her in-class activities in either class as a result of the information she was given through the formative assessments. This situation, however, may not be the case for a beginning teacher who has little experience with the concepts or procedures that students may find difficult to grasp. Video explanations with embedded formative assessment, as used as the pre-class activity in this research, could potentially provide a beginning teacher with a substantial "head start". Without requiring the years of experience, they would have the capacity to immediately utilise formative assessment results to gain an understanding of the concepts students find difficult after their content explanation. Alongside gaining a broader perspective on the concepts students find difficult, they would have the capacity to refine their explanations for the in-class component if they noted any ambiguity in their explanation that may have led to student confusion.

7.10 Concluding Statements on Contribution to Research Field

While other research has focused attention on student achievement, predominately measuring raw score changes to test scores or exam grades to determine the impact of the flipped classroom, this research focused on student understanding, utilising research-validated instruments. This research is the first to examine the impact of the flipped classroom approach on secondary school students' understanding of solving linear equations. While no difference was apparent in the pre- and post-topic understanding between flipped and regular groups, favourable retention in understanding was observed for the flipped group in the delayed testing when compared with the regular group.

No statistical significance was apparent between groups for any attitude subscale; however, the literature has not always consistently demonstrated significant differences to attitude (e.g., Lo & Hew, 2017) in international studies, and this research provides an Australian context to this. Qualitative analysis revealed an enhanced capacity of the flipped classroom students to self-report a favourable response to learning mathematics with technology, and it is postulated that students in this study recognised more purpose for the use of technology in learning mathematics through a technology-enabled flipped format than they had previously done through the regular classroom format, which also involved technology. Furthermore, the teacher interviews demonstrated that, at the least, a flipped classroom can help to support positive attitudes in the classroom that are more conducive to collaboration between peers and teacher than a regular approach. This enhanced classroom environment complements the findings of a previous Australian case study of 27 Year 10 students (Muir & Geiger, 2016).

This research supports the notion that the capacity to review instructional content is seen as a hallmark positive for participation in the flipped classroom, with students overwhelmingly commenting that this feature assisted with concentration, focus, and understanding of content. This research also widely reinforces the notion that students prefer videos that are created by their teacher, primarily because they have trust in their teacher's mathematical knowledge and have an understanding of their methods for approaching questions. They did not want to be confused through differing methodologies that may be available to them on the internet, and nor would they have trust in what other videos may have to offer. Students in this research had an overwhelmingly positive response to the flipped classroom and wanted to see this as a way of learning in the future. This is a point of contention in the literature (see Sections 2.6.1 and 2.6.2). Given the differences in study design between this and other research (i.e., duration, pre-class activities, and in-class activities), it is difficult to attribute these differing findings to a specific aspect of the flipped classroom. However, given there was a change only to the pre-class component, this research highlights that perhaps the pre-class component is the responsible mechanism for eliciting positive responses from students.

The teacher perspectives and experiences primarily reinforce what is prevalent through the flipped classroom literature; a significant amount of planning time is required to implement a flipped classroom. It does, however, replicate this in an Australian secondary school context and shows that the time pressure and level of stress felt during the in-class components substantially decrease as a result of implementation.

Highlighted in Lo et al.'s (2017) advice for future research was the need for researchers to use an online system capable of tracking student use, and this was utilised in this research. This allowed further insights into student participation and the ability to account for stagnation in understanding for two students. Furthermore, Lo et al. (2017) indicated the difficulty in determining the success of the flipped classroom resulting from authors failing to discuss the types of questions they had used to assess student achievement and provide advice for future research to include this. This present research responds to this advice by detailing the types of questions used to determine understanding and the rationale behind these questions to help better the available literature. Furthermore, this research contributes to the stringent design required to help better account for the effectiveness of the flipped classroom in different situations, as called for by Låg and Sæle (2019) in their meta-analysis. In-class and pre-class activities were documented, alongside the description of experimental and control conditions, and instruments were used to measure understanding. This helps to sharpen what Låg and Sæle (2019) termed a "blurry picture" (p. 3) of the flipped classroom literature.

Ultimately, few differences were observed between the international studies presented in the literature review and this one. The flipped classroom provided more opportunities for students to complete work in class. As a direct effect of this, there were more opportunities for the teacher to assist students through the additional time available in class. This research shows that the change in pre-class activity is enough to generate this impact and, at the very least, students' understanding and attitudes hold pace with the regular group. The flipped classroom begins to show promise over the longer duration for students (i.e., through the delayed testing in this research) and teacher (i.e., reusable content after creating; decreased time pressures in class). The improvement to student outcomes after delayed testing contrasts with findings in the literature (e.g., Love et al., 2014); however, this may be design or duration related, with the duration of this research less than that of Love et al.'s.

7.11 Future Directions for Research

Further research is warranted in the secondary school mathematics environment. There is discrepancy in the ability for all research to demonstrate positive improvements to student achievement through the use of a flipped classroom, and a more focused approach on understanding may begin to reveal the reasons behind this. Lo et al. (2017) reported on the difficulty of investigating the effects of the flipped classroom on the types of questions used in assessments because most studies do not report on the questions used when discussing achievement. A focus on understanding, with research-based instrumentation that aims to reveal understanding, will help to better determine the impact of the flipped classroom. This is particularly poignant when others have suggested, for example, that “perhaps inverting a classroom might not be the best pedagogy to use with conceptual material” (Kennedy et al., 2015, p. 13)

Further research on the impact of flipped classroom components, with respect to the contribution of changing only the pre-class or in-class activities and and the combination of changing both components in a range of mathematics topics require further investigation. The current research changed only the pre-class component and found no substantial differences in student understanding or attitude between pre- and post-testing. It noted, however, a change in the delayed testing results for the flipped classroom students. This contrasts with DeSantis et al.’s (2015) conclusion that “the simple replacement of a lecture with streaming video is unlikely to be the mechanism responsible for success” (p. 52). Bergmann and Sams’s (2016) contention that a flipped classroom is the blending of direct instruction with a constructivist (inquiry/discovery based) approach, and given this research did not alter the structure or format of the in-class component (aside from having more time to work with students), there is room to build upon this research and determine if changes to in-class structures have any further impact. Any change to the in-class activities in the flipped group should also be replicated in the control group to ensure that the alteration of in-class activities is not the contributing factor to success, as suggested by Jensen et al. (2015).

Scaling this research up to include multiple schools and multiple topics for longer duration interventions would help provide valuable, and generalisable, insights into the effectiveness of the flipped classroom approach in secondary education. Future research that compares a flipped classroom to a teacher’s regular approach should ensure that the control group does not have access to the flipped content so that appropriate comparisons can be made between two distinct classroom groups.

References

Abeysekera, L., & Dawson, P. (2015). Motivation and cognitive load in the flipped classroom: Definition, rationale and a call for research. *Higher Education Research & Development*, *34*(1), 1–14. https://doi.org/10.1080/07294360.2014.934336

Adams, C., & Dove, A. (2016). Flipping calculus: The potential influence, and the lessons learned. *Electronic Journal of Mathematics & Technology*, *10*(3), 155-164.

Aiken, L. R. (1970). Attitudes toward mathematics. *Review of educational research, 40*(4), 551–596. https://doi.org/10.3102/00346543040004551

Akçayır, G., & Akçayır, M. (2018). The flipped classroom: A review of its advantages and challenges. *Computers & Education*, *126*, 334–345. https://doi.org/10.1016/j.compedu.2018.07.021

Akhtar, Z., & Steinle, V. (2013) Probing students' numerical misconceptions in school algebra. In V. Steinle, L. Ball, & C. Bardini (Eds.) *Mathematics education: Yesterday, today and tomorrow: Proceedings of the 36th Annual Conference of the Mathematics Education Research Group of Australasia, Melbourne, 7–11 July 2013* (pp. 36–43). MERGA.

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology*, *103*(1), 1-18. https://doi.org/10.1037/a0021017

Anderson, L., & Brennan, J. P. (2015). An experiment in "flipped" teaching in freshman calculus. *Primus, 25*(9–10), 861–875. https://doi.org/10.1080/10511970.2015.1059916

American Psychological Association. (2020). *Publication manual of the American Psychological Association* (7th ed.). Author.

Baker, J. W. (2000). The "classroom flip": Using web course management tools to become the guide by the side. In J. A. Chambers (Ed.), *Selected papers from the 11th International Conference on College Teaching and Learning* (pp. 9–17). Florida Community College at Jacksonville.

Baker, J. W. (2011*). The origins of "the classroom flip"* [Unpublished manuscript]. Department of Media & Applied Communications, Cedarville University.

Ball, L. (2011). Analysing interview data for clusters and themes. In J. Clark, B. Kissane, J. Mousley, T. Spencer, & S. Thornton (Eds.), *Mathematics: Traditions and (new) practices: Proceedings of the 34th annual conference of the Mathematics Education Research Group of Australasia and the Association of Mathematics Teachers. AAMT–MERGA Conference, Adelaide, 3–7 July 2011* (pp. 89–97). MERGA and AAMT.

Barkatsas, A. T., Kasimatis, K., & Gialamas, V. (2009). Learning secondary mathematics with technology: Exploring the complex interrelationship between students' attitudes, engagement, gender and achievement. *Computers & Education*, *52*(3), 562–570. https://doi.org/10.1016/j.compedu.2008.11.001

Bergmann, J., & Sams, A. (2009). Remixing chemistry class: Two Colorado teachers make vodcasts of their lectures to free up class time for hands-on activities. *Learning & Leading with Technology*, *36*(4), 22–27.

Bergmann, J., & Sams, A. (2016). *Flipped learning for maths instruction*. Hawker Brownlow Education.

Bhagat, K. K., Chang, C. N., & Chang, C. Y. (2016). The impact of the flipped classroom on mathematics concept learning in high school. *Journal of Educational Technology & Society*, *19*(3), 134–142.

Bhowmik, M., & Roy, B. B. (2016). A study on the relationship between achievement in mathematics and attitude towards mathematics of secondary school students. *Scholar*, *1*(2).

Bishop, J. L., & Verleger, M. A. (2013). The flipped classroom: A survey of the research. *Proceedings of the 120th American Society for Engineering Education National Conference, Atlanta, 23–26 June 2013,* (pp. 1–18). ASEE.

Boaler, J., Dieckmann, J. A., Pérez-Núñez, G., Sun, K. L., & Williams, C. (2018). Changing students' minds and achievement in mathematics: The impact of a free online student course. *Frontiers in Education*, *3*(26), 1–7. https://doi.org/10.3389/feduc.2018.00026

Booth, L. R. (1988). Children's difficulties in beginning algebra. In A.F. Coxford (Ed.), *The ideas of algebra, K–12* (pp. 20–32). National Council of Teachers of Mathematics.

Bracht, G. H., & Glass, G. V. (1968). The external validity of experiments. *American Educational Research Journal*, *5*(4), 437–474. https://doi.org/10.3102/00028312005004437

Brunsell, E., & Horejsi. M. (2013). Flipping your classroom in one 'take'. *The Science Teacher*, *80*(3), 8.

Campbell, D. T., & Stanley, J. C. (1963). *Experimental and quasi-experimental designs for research*. Rand McNally College Publishing Company.

Chao, C. Y., Chen, Y. T., & Chuang, K. Y. (2015). Exploring students' learning attitude and achievement in flipped learning supported computer aided design curriculum: A study in high school engineering education. *Computer Applications in Engineering Education*, *23*(4), 514-526. https://doi.org/10.1002/cae.21622

Chen, Y., Wang, Y., Kinshuk, & Chen, N-S. (2014). Is FLIP enough? Or should we use the FLIPPED model instead? *Computers & Education*, *79*, 16–27. https://doi.org/10.1016/j.compedu.2014.07.004

Chick, H. (2009). Teaching the distributive law: Is fruit salad still on the menu? In R. Hunter, B. Bicknell, T. Burgess (Eds.). *Proceedings of the 32nd Annual Conference of the Mathematics Education Research Group of Australasia, Wellington, 5–9 July 2009* (Vol. 1, pp. 121–128). MERGA.

Clark, K. R. (2015). The effects of the flipped model of instruction on student engagement and performance in the secondary mathematics classroom. *Journal of Educators Online*, *12*(1), 91–115.

Colton, C., & Smith, W. M. (2014). Successfully transitioning to linear equations. *The Mathematics Teacher, 107*(6), 452–457. https://10.5951/mathteacher.107.6.0452

Cook, T. D., & Campbell, D. T. (1979). *Quasi-experimentation: Design and analysis issues for field settings.* Houghton Mifflin Company.

Daskalogianni, K., & Simpson, A. (2000). Towards a definition of attitude: The relationship between the affective and the cognitive in pre-university students. In T. Nakahara and M. Koyama (Eds.). *Proceedings of the 24th Conference of the International Group for the Psychology of Mathematics Education*, *Hiroshima, 23–27 July*, (Vol. 2, pp. 2–217).

Digital Education Advisory Group (DEAG). (2013). *Beyond the classroom: A new digital education for young Australians in the 21st century.* Retrieved from http://apo.org.au/node/34413

Department of Education, Employment and Workplace Relations (DEEWR). (2013). *Digital Education Revolution mid-program review.* Retrieved from https://docs.education.gov.au/system/files/doc/other/digital_education_revolution_program_review.pdf

Di Martino, P., & Zan, R. (2015). The construct of attitude in mathematics education. In B. Pepin & B. Roesken-Winter (Eds.), *From beliefs to dynamic affect systems in mathematics education* (pp. 51–72). Springer. https://doi.org/10.1007/978-3-319-06808-4_3

DeBellis, V. A., & Goldin, G. (1997). The affective domain in mathematical problem solving. In E. Pehkonen (Ed.) *Proceedings of the 21st Conference of the International Group for the Psychology of Mathematics Education, Finland, 14–19 July 1997* (Vol. 2, pp. 209–216). University of Helsinki.

DeSantis, J., Van Curen, R., Putsch, J., & Metzger, J. (2015). Do students learn more from a flip? An exploration of the efficacy of flipped and traditional lessons. *Journal of Interactive Learning Research, 26*(1), 39–63.

Deslauriers, L., Schelew, E., & Wieman, C. (2011). Improved learning in a large-enrollment physics class. *Science*, *332*(6031), 862–864. https://doi.org/10.1126/science.1201783

Drever, E. (1995). *Using semi-structured interviews in small-scale research: A teacher's guide*. Scottish Council for Research in Education.

Drijvers, P., Goddijn, A., & Kindt, M. (2010). Algebra education: exploring topics and themes. In P. Drijvers (Ed.), *Secondary algebra education. Revisiting topics and themes exploring the unknown* (pp. 5–26). Brill Sense.

Dunham, P. H. (1990). *Mathematical confidence and performance in technology-enhanced precalculus: Gender-related differences* [Unpublished doctoral dissertation, The Ohio State University].

Eccles, J. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.), Achievement and achievement motives: Psychological and sociological approaches (pp. 75–146). W. H. Freeman.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual review of Psychology*, *53*(1), 109–132. https://doi.org/10.1146/annurev.psych.53.100901.135153

Filloy, E., & Rojano, T. (1984). From an arithmetical to an algebraic thought (A clinical study with 12–13 years old). In J.M. Moser (Ed.), *Proceedings of the 6th Conference of the International Group for the Psychology of Mathematics Education, Wisconsin, 18–23 July 1982* (pp. 51–56).

Filloy, E., & Rojano, T. (1989). Solving equations: The transition from arithmetic to algebra. *For the Learning of Mathematics*, *9*(2), 19–25.

Finkel, E. (2012). Flipping the script in K12. *District Administration*, *48*(10), 28.

Flipped Learning Network (FLN). (n.d.). *FLIP learning: A community resource brought to you by the Flipped Learning Network.* Retrieved from https://flippedlearning.org

Fredricks, J., Blumenfeld, P., & Paris, A. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59–109. https://doi.org/10.3102/00346543074001059

Fulton, K. (2012). Upside down and inside out: Flip your classroom to improve student learning. *Learning & Leading with Technology*, *39*(8), 12–17.

Gasco, J., & Villarroel, J. D. (2012). Algebraic problem solving and learning strategies in compulsory secondary education. *Procedia-Social and Behavioral Sciences*, *46*, 612–616. https://doi.org/10.1016/j.sbspro.2012.05.172

Galbraith, P., & Haines, C. (1998). Disentangling the nexus: Attitudes to mathematics and technology in a computer learning environment. *Educational Studies in Mathematics*, *36*(3), 275–290. https://doi.org/10.1023/A:1003198120666

González-Gómez, D., Jeong, J. S., & Rodríguez, D. A. (2016). Performance and perception in the flipped learning model: An initial approach to evaluate the effectiveness of a new teaching methodology in a general science classroom. *Journal of Science Education and Technology*, *25*(3), 450–459. https://doi.org/10.1007/s10956-016-9605-9

Goodwin, B., & Miller, K. (2013). Evidence on flipped classrooms is still coming in. *Educational Leadership*, *70*(6), 78–80.

Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education*, *57*(3), 1953–1960. https://doi.org/10.1016/j.compedu.2011.04.010

Graziano, K. J., Herring, M. C., Carpenter, J. P., Smaldino, S., & Finsness, E. S. (2017). A TPACK diagnostic tool for teacher education leaders. *TechTrends*, *61*(4), 372–379. https://doi.org/10.1007/s11528-017-0171-7

Groff, J., & Mouza, C. (2008). A framework for addressing challenges to classroom technology use. *AACE Journal*, *16*(1), 21–46.

Grypp, L., & Luebeck, J. (2015). Rotating solids and flipping instruction. *Mathematics Teacher*, *109*(3), 186–193. https://doi.org/10.5951/mathteacher.109.3.0186

Guerrero, S., Beal, M., Lamb, C., Sonderegger, D., & Baumgartel, D. (2015). Flipping undergraduate finite mathematics: Findings and implications. *PRIMUS*, *25*(9–10), 814–832. https://doi.org/10.1080/10511970.2015.1046003

Gundlach, E., Richards, K. A. R., Nelson, D., & Levesque-Bristol, C. (2015). A comparison of student attitudes, statistical reasoning, performance, and perceptions for web-augmented traditional, fully online, and flipped sections of a statistical literacy class. *Journal of Statistics Education*, *23*(1). https://doi.org/10.1080/10691898.2015.11889723

Halili, S. H., & Zainuddin, Z. (2015). Flipping the classroom: What we know and what we don't. *The Online Journal of Distance Education and E-Learning*, 3(1), 28–35.

Hart L. (1989) Describing the affective domain: Saying what we mean. In D.B. McLeod & V.M. Adams (Eds.), *Affect and mathematical problem solving.* Springer. https://doi.org/10.1007/978-1-4612-3614-6_3

Hattie, J. (2008). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement.* Routledge.

Herreid, C. F., & Schiller, N. A. (2013). Case studies and the flipped classroom. *Journal of College Science Teaching*, *42*(5), 62–66.

Herscovics, N., & Linchevski, L. (1994). A cognitive gap between arithmetic and algebra. *Educational Studies in Mathematics*, *27*(1), 59–78.

Hollowell, K. A., & Duch, B. J. (1991, April). *Functions and statistics with computers at the college level.* [Paper presentation]. American Educational Research Association Annual Conference, Chicago, IL, United States.

Huntley, M. A., Marcus, R., Kahan, J., & Miller, J. L. (2007). Investigating high-school students' reasoning strategies when they solve linear equations. *The Journal of Mathematical Behavior*, *26*(2), 115–139. https://doi.org/10.1016/j.jmathb.2007.05.005

Institute of Professional Editors. (2019). *Guidelines for editing research theses*. Retrieved from http://iped-editors.org/About_editing/Editing_theses.aspx

Jensen, J. L., Kummer, T. A., & Godoy, P. D. D. M. (2015). Improvements from a flipped classroom may simply be the fruits of active learning. *CBE—Life Sciences Education*, *14*(1), ar5. https://doi.org/10.1187/cbe.14-08-0129

Johnson, L., & Renner, J. (2012). *Effect of the flipped classroom model on secondary computer applications course: Student and teacher perceptions, questions and student achievement.* [Unpublished doctoral dissertation]. University of Louisville, Louisville, Kentucky.

Kadry, S., & El Hami, A. (2014). Flipped classroom model in calculus II. *Education*, *4*(4), 103–107. https://doi.org/10.5923/j.edu.20140404.04

Kay, R., & Kletskin, I. (2012). Evaluating the use of problem-based video podcasts to teach mathematics in higher education. *Computers & Education*, *59*(2), 619–627. https://doi.org/10.1016/j.compedu.2012.03.007

Kearney, M., Schuck, S., Aubusson, P., & Burke, P. F. (2018). Teachers' technology adoption and practices: Lessons learned from the IWB phenomenon. *Teacher Development*, *22*(4), 481–496. https://doi.org/10.1080/13664530.2017.1363083

Kennedy, E., Beaudrie, B., Ernst, D. C., & St. Laurent, R. (2015). Inverted pedagogy in second semester calculus. *PRIMUS*, *25*(9–10), 892–906. https://doi.org/10.1080/10511970.2015.1031301

Kieran, C. (1981). Concepts associated with the equality symbol. *Educational studies in Mathematics*, *12*(3), 317–326. https://doi.org/10.1007/BF00311062

Kieran, C. (1992). The learning and teaching of school algebra. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics* (pp. 390–419). Macmillan.

Kieran, C. (2004). Algebraic thinking in the early grades: What is it? *The Mathematics Educator*, *8*(1), 139–151.

Kieran, C. (2013). The false dichotomy in mathematics education between conceptual understanding and procedural skills: An example from algebra. In K. R. Leatham (Ed.), *Vital directions for mathematics education research* (pp. 153–171). Springer. https://doi.org/10.1007/978-1-4614-6977-3_7

Kirvan, R., Rakes, C. R., & Zamora, R. (2015). Flipping an algebra classroom: Analyzing, modeling, and solving systems of linear equations. *Computers in the Schools, 32*(3–4), 201–223. https://doi.org/10.1080/07380569.2015.1093902

Kiwanuka, H. N., Van Damme, J., Van Den Noortgate, W., Anumendem, D. N., Vanlaar, G., Reynolds, C., & Namusisi, S. (2017). How do student and classroom characteristics affect attitude toward mathematics? A multivariate multilevel analysis. *School Effectiveness and School Improvement*, *28*(1), 1–21. https://doi.org/10.1080/09243453.2016.1201123

Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content knowledge (TPACK)? *Journal of Education*, *193*(3), 13–19. https://doi.org/10.1177/002205741319300303

Kozioff, M. A., LaNunziata, L., Cowardin, J., & Bessellieu, F. B. (2000). Direct instruction: Its contributions to high school achievement. *The High School Journal*, *84*(2), 54–71. https://doi.org/10.2307/40364405

Kuiper, S. R., Carver, R. H., Posner, M. A., & Everson, M. G. (2015). Four perspectives on flipping the statistics classroom: Changing pedagogy to enhance student-centered learning. *Primus*, *25*(8), 655–682. https://doi.org/10.1080/10511970.2015.1045573

Kulm, G. (1980). Research on mathematics attitude. In R. J. Shumway (Ed.), *Research in mathematics education* (pp. 356–387). NCTM.

Lage, M. J., Platt, G. J., & Treglia, M. (2000). Inverting the classroom: A gateway to creating an inclusive learning environment. *Journal of Economic Education*, *31*(1), 30–43. https://doi.org/10.1080/00220480009596759

Låg, T., & Sæle, R. G. (2019). Does the flipped classroom improve student learning and satisfaction? A systematic review and meta-analysis. *AERA Open*, *5*(3), 1-17. https://doi.org/10.1177/2332858419870489

Lewis, J. M., & Blunk, M. L. (2012). Reading between the lines: Teaching linear algebra. *Journal of Curriculum Studies*, *44*(4), 515–536. https://doi.org/10.1080/00220272.2012.716975

Liem, G. A. D., & Martin, A. J. (2013). Direct instruction and academic achievement. In J. Hattie & E. Anderman (Eds.), *International guide to student achievement*. Routledge.

Linsell, C. (2009). A hierarchy of strategies for solving linear equations. In R. Hunter, B. Bicknell, & T. Burgess (Eds.), *Crossing divides: Proceedings of the 32nd Annual Conference of the Mathematics Education Research Group of Australasia*, *Palmerston North*, *New Zealand, 5–9 July 2009* (vol. 1, pp. 331–338). MERGA.

Linsell, C. (2010). Secondary Numeracy Project: Students' development of algebraic knowledge and strategies. In Ministry of Education (Ed.), *Findings from the New Zealand numeracy development projects 2009* (pp. 100–117). Learning Media

Lo, C. K., & Hew, K. F. (2017). A critical review of flipped classroom challenges in K–12 education: Possible solutions and recommendations for future research. *Research and Practice in Technology Enhanced Learning*, *12*(1), 4. https://doi.org/10.1186/s41039-016-0044-2

Lo, C. K., Hew, K. F., & Chen, G. (2017). Toward a set of design principles for mathematics flipped classrooms: A synthesis of research in mathematics education. *Educational Research Review*, *22*, 50–73. https://doi.org/10.1016/j.edurev.2017.08.002

Love, B., Hodge, A., Corritore, C., & Ernst, D. C. (2015). Inquiry-based learning and the flipped classroom model. *Primus*, *25*(8), 745–762. https://doi.org/10.1080/10511970.2015.1046005

Love, B., Hodge, A., Grandgenett, N., & Swift, A. W. (2014). Student learning and perceptions in a flipped linear algebra course. *International Journal of Mathematical Education in Science and Technology*, *45*(3), 317–324. https://doi.org/10.1080/0020739X.2013.822582

Ma, X., & Kishor, N. (1997). Assessing the relationship between attitude toward mathematics and achievement in mathematics: A meta-analysis. *Journal for Research in Mathematics Education*, 26–47. https://doi.org/10.2307/749662

Maccini, P., & Gagnon, J. C. (2000). Best practices for teaching mathematics to secondary students with special needs. *Focus on Exceptional Children*, *32*(5), 1–22.

MacGregor, M., & Stacey, K. (1997). Students' understanding of algebraic notation: 11–16. *Educational studies in mathematics*, *33*(1), 1–19. https://doi.org/10.1023/A:1002970913563

Marks, H. M. (2000). Student engagement in instructional activity: Patterns in the elementary, middle, and high school years. *American Educational Research Journal*, *37*(1), 153–184. https://doi.org/10.3102/00028312037001153

Martin, A. J. (2015). Teaching academically at risk students in middle school: The roles of explicit instruction and guided discovery learning. *Big Fish, Little Fish: Teaching and Learning in the Middle Years*, 29–43.

McGivney-Burelle, J., & Xue, F. (2013). Flipping calculus. *Primus*, *23*(5), 477–486. https://doi.org/10.1080/10511970.2012.757571

McLeod, D. B. (1992). Research on affect in mathematics education: A reconceptualization. *Handbook of Research on Mathematics Teaching and Learning*, *1*, 575–596.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers college record*, *108*(6), 1017–1054.

Molina, M., Rodríguez-Domingo, S., Cañadas, M. C., & Castro, E. (2017). Secondary school students' errors in the translation of algebraic statements. *International Journal of Science and Mathematics Education*, *15*(6), 1137–1156. https://doi.org/10.1007/s10763-016-9739-5

Moyle, K. (2010). *Building innovation: Learning with technologies.* ACER Press.

Muir, T., & Chick, H. (2014). Flipping the classroom: A case study of a mathematics methods class. In J. Anderson, M. Cavanagh, & A. Prescott (Eds.), *Curriculum in focus: Research guided practice. Proceedings of the 37th annual conference of the Mathematics Education Research Group of Australasia, Sydney, 29 June–03 July 2014 (pp. 485*–492), MERGA.

Muir, T., & Geiger, V. (2016). The affordances of using a flipped classroom approach in the teaching of mathematics: A case study of a grade 10 mathematics class. *Mathematics Education Research Journal*, *28*(1), 149–171. https://doi.org/10.1007/s13394-015-0165-8

O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *The Internet and Higher Education*, 25, 85–95. https://doi.org/10.1016/j.iheduc.2015.02.002

Pierce, R., Stacey, K., & Barkatsas, A. (2007). A scale for monitoring students' attitudes to learning mathematics with technology. *Computers & Education, 48*(2), 285–300. https://doi.org/10.1016/j.compedu.2005.01.006

Price, B., Stacey, K., Steinle, V., Chick, H., & Gvozdenko, E. (2009). *Getting SMART about assessment for learning.* [Paper presentation]. Conference of the International Society for Design and Development in Education, Cairns, 28

September–01 October 2009. Retrieved from http://www.isdde.org/isdde/cairns/pdf/papers/isdde09_stacey.pdf

Price, B., Stacey, K., Steinle, V., Gvozdenko, E. (2013). SMART online assessments for teaching mathematics. *Mathematics Teaching (235)*, 10–15.

Rasch, D., Kubinger, K. D., & Moder, K. (2011). The two-sample t test: pre-testing its assumptions does not pay off. Statistical papers, 52(1), 219-231. https://doi.org/10.1007/s00362-009-0224-x

Rochon, J., Gondan, M., & Kieser, M. (2012). To test or not to test: Preliminary assessment of normality when comparing two independent samples. BMC medical research methodology, *12*(1), 81. https://doi.org/10.1186/1471-2288-12-81

Roehl, A., Reddy, S., & Shannon, G. (2013). The flipped classroom: An opportunity to engage millennial students through active learning strategies. *Journal of Family & Consumer Sciences*, *105*(2), 44-49.

Ronda, E. R. (2009). Growth points in students' developing understanding of function in equation form. *Mathematics Education Research Journal*, *21*(1), 31–53. https://doi.org/10.1007/BF03217537

Rosenshine, B. V. (1986). Synthesis of research on explicit teaching. *Educational Leadership*, *43*(7), 60–69.

Rosenshine, B.V. (2008). *Five meanings of direct instruction.* Center on Innovation and Improvement.

Ruddick, K. (2012). *Improving chemical education from high school to college using a more hands-on approach.* [Doctoral dissertation, The University of Memphis]. ProQuest Digital Dissertations.

Sahin, A., Cavlazoglu, B., & Zeytuncu, Y. E. (2015). Flipping a college calculus course: A case study. *Journal of Educational Technology & Society*, *18*(3), 142–152.

Sams, A., & Bergmann, J. (2013). Flip your students' learning. *Educational Leadership*, *70*(6), 16–20.

Sfard, A., & Linchevski, L. (1994). The gains and the pitfalls of reification: The case of algebra. *Educational Studies in Mathematics*, *26*, 191–1228). https://doi.org/10.1007/978-94-017-2057-1_4

Sherwood, C. (1993). Australian experiences with the effective classroom integration of information technology: Implications for teacher education. *Journal of Information Technology for Teacher Education*, *2*(2), 167–179. https://doi.org/10.1080/0962029930020205

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational researcher, 15*(2), 4–14. https://doi.org/10.3102/0013189X015002004

Simsek, E., Xenidou-Dervou, I., Karadeniz, I., & Jones, I. (2019). The conception of substitution of the equals sign plays a unique role in students' algebra performance. *Journal of Numerical Cognition, 5*(1), 24–37. https://doi.org/10.5964/jnc.v5i1.147

Smith, J. P. (2015). *The efficacy of a flipped learning classroom.* [Doctoral dissertation, McKendree University].

Speller, S. (2015). *Mathematics teacher's experience with flipped learning: A phenomenographic approach.* [Unpublished doctoral dissertation]. The University of Toledo.

Srivastava, P., & Hopwood, N. (2009). A practical iterative framework for qualitative data analysis. *International Journal of Qualitative Methods*, *8*(1), 76–84. https://doi.org/10.1177/160940690900800107

Stacey, K., & MacGregor, M. (2000). Learning the algebraic method of solving problems. *Journal of Mathematical Behavior, 18* (2), 149–167. https://doi.org/10.1016/S0732-3123(99)00026-7

Stacey, K., Price, B., Gvozdenko, E., & Steinle, V., & Chick, H (2011a). *Specific Mathematics Assessments that Reveal Thinking.* Retrieved from http://www.smart-quiz.edu.au/teacher/

Stacey, K., Price, B., Gvozdenko, E., & Steinle, V., & Chick, H (2011b). *Specific Mathematics Assessments that Reveal Thinking.* Retrieved from https://www.smartvic.com/smart/usesmart/conceptualgrowth.html

Stacey, K., Price, B., & Steinle, V. (2012). Identifying stages in a learning hierarchy for use in formative assessment: The example of line graphs. In J. Dindyal, L. P. Cheng, & S. F. Ng (Eds.), *Mathematics education: Expanding horizons. Proceedings of the 35th Mathematics Education Research Group of Australasia, Adelaide, 2*–6 July 2012. MERGA

Star, J. R., & Rittle-Johnson, B. (2008). Flexibility in problem solving: The case of equation solving. *Learning and Instruction*, *18*(6), 565–579. https://doi.org/10.1016/j.learninstruc.2007.09.018

Stein, M., Silbert, J., & Carnine, D. (1997). *Designing effective mathematics instruction: A direct instruction approach*. Prentice-Hall.

Strayer, J. F. (2012). How learning in an inverted classroom influences cooperation, innovation and task orientation. *Learning Environments Research*, *15*(2), 171–193. https://doi.org/10.1007/s10984-012-9108-4

Szparagowski, R. (2014). Effectiveness of the flipped classroom. [Honors project]. Retrieved from https://scholarworks.bgsu.edu/honorsprojects/127

Talbert, R. (2015). Inverting the transition-to-proof classroom. *Primus*, *25*(8), 614–626. https://doi.org/10.1080/10511970.2015.1050616

Trochim, W. M. (2020. *The research methods knowledge base* (2nd ed.). Retrieved from http://www.socialresearchmethods.net/

Tucker, B. (2012). The flipped classroom. *Education Next*, *12*(1), 82–83.

van Teijlingen, E. (2014)). *Semi-structured interviews.* Retrieved from http://www.fao.org/docrep/x5307e/x5307e08.htm

Victorian Curriculum and Assessment Authority (VCAA). (n.d.). *Mathematics structure*. Retrieved from http://victoriancurriculum.vcaa.vic.edu.au/mathematics/introduction/structure

Walser, T. M. (2014). Quasi-experiments in schools: The case for historical cohort control groups. *Practical Assessment, Research & Evaluation*, *19*(6), 2–10. https://doi.org/10.7275/17hj-1k58

Wanner, T., & Palmer, E. (2015). Personalising learning: Exploring student and teacher perceptions about flexible learning and assessment in a flipped university course. *Computers & Education, 88*(1), 354–369. https://doi.org/10.1016/j.compedu.2015.07.008

Watt, H. M. (2006). The role of motivation in gendered educational and occupational trajectories related to maths. *Educational Research and Evaluation*, *12*(4), 305–322. https://doi.org/10.1080/13803610600765562

Welder, R. M. (2012). Improving algebra preparation: Implications from research on student misconceptions and difficulties. *School science and mathematics*, *112*(4), 255–264. https://doi.org/10.1111/j.1949-8594.2012.00136.x

Wigfield, A., & Cambria, J. (2010). Students' achievement values, goal orientations, and interest: Definitions, development, and relations to achievement outcomes. *Developmental Review*, *30*(1), 1–35. https://doi.org/10.1016/j.dr.2009.12.001

Wigfield, A., & Eccles, J. S. (1992). The development of achievement task values: A theoretical analysis. *Developmental Review, 12*(3), 265–310. https://doi.org/10.1016/0273-2297(92)90011-P

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology*, *25*(1), 68–81. https://doi.org/10.1006/ceps.1999.1015

Yarbro, J., Arfstrom, K.M., McKnight, K., McKnight, P. (2014) *Extension of a review of flipped learning*. Retrieved from https://flippedlearning.org/wp-content/uploads/2016/07/Extension-of-FLipped-Learning-LIt-Review-June-2014.pdf

Zan, R., Brown, L., Evans, J., & Hannula, M. S. (2006). Affect in mathematics education: An introduction. *Educational Studies in Mathematics*, *63*(2), 113–121. https://doi.org/10.1007/s10649-006-9028-2

Appendices

Appendix A. Catholic Education Melbourne Ethics Approval

Dear Mr McAlindon

Congratulations, your research application, 0727 - 'The Effect of a Flipped Classroom Approach on Student Perception and Achievement in Linear Equations.', has been approved by Catholic Education Melbourne.

I am pleased to advise that your research application is approved in principle subject to the eight standard conditions outlined below.

1. The decision as to whether or not research can proceed in a school rests with the school's principal, so you will need to obtain their approval directly before commencing any research activity. You should provide the principal with an outline of your research proposal and indicate what will be asked of the school. A copy of this email of approval, and a copy of notification of approval from your organisation's/university's Ethics Committee, should also be provided.

2. A copy of the approval notification from your institution's Ethics Committee must be forwarded to this Office (if not already provided), together with any modifications to your research protocol requested by the Committee. You may not start any research in Catholic schools until this step has been completed.

3. A Working with Children (WWC) check – or registration with the Victorian Institute of Teaching (VIT) – is necessary for all researchers visiting schools. Appropriate documentation must be shown to the principal before starting the research in the school.

4. No student is to participate in the research study unless s/he is willing to do so and consent is given by a parent/guardian.

5. Any substantial modifications to the research proposal, or additional research involving use of the data collected, will require a further research application to be submitted to Catholic Education Melbourne.

6. Data relating to individuals or the school are to remain confidential and protected in line with the Privacy Act 1988 (Commonwealth).

7. Since participating schools have an interest in research findings, you should consider ways in which the results of the study could be made available for the benefit of the school community.

8. At the conclusion of the study, a copy or summary of the research findings should be forwarded to Catholic Education Melbourne. It would be appreciated if you could submit this via email to research@cem.edu.au.

I wish you well with your research study. The information provided in your proposal is now closed for further changes. If you have any queries concerning this matter or need to make amendments in the future, please contact research@cem.edu.au.

Yours sincerely

Mr Jim Miles
DIRECTOR ENTERPRISE SERVICES
Catholic Education Melbourne

Appendix B. Principal Plain Language Statement and Consent Form

Principal Plain Language Statement

Project: The Effect of a Flipped Classroom Approach on Student Perception and Achievement in Linear Equations.

We would like to invite [redacted] to participate in the above research project, which is being conducted by Mr Andrew McAlindon (Doctor of Education candidate), Dr Lynda Ball (Melbourne Graduate School of Education) and Assoc. Prof. Shanton Change (School of Computing and Information Systems). Catholic Education Melbourne and the University of Melbourne Human Research Ethics Committee have approved this project.

Should you agree for your school to participate in the project then this would involve 1-2 volunteer teachers who teach Year 9 mathematics, as well as the students in their Year 9 mathematics classes where the project will be implemented.

This research project aims to compare the impact of two teaching approaches (flipped vs. non-flipped) within a 'linear equations' unit in two Year 9 mathematics classes. It will compare the student understanding of concepts and skills associated with solving linear equations between the two classes. Additionally, it will compare the student perception of mathematics learning within/between each class. The teacher insights when implementing a new lesson structure whilst teaching students to solve linear equations will also be gathered. Through a case study of one flipped and one non-flipped year 9 mathematics class in the topic of linear equations, this project will provide insight on the impact a flipped approach can have on both students' achievement and their perceptions of mathematics. It will also provide an opportunity to discuss a teacher's experience in implementing this approach in one year 9 mathematics topic.

The teacher of the flipped classroom will:

- Create up to 15 lessons on linear equations using the platform 'EdPuzzle'[1]. Instructions on how to access and use the EdPuzzle platform will be provided by Andrew McAlindon through an initial demonstration. Andrew will also provide ongoing technical assistance throughout the duration of the project, where necessary. Each online lesson will take around twenty minutes to prepare for, so a total of 300 minutes of additional planning time will be required by the teacher/s.
- Administer pre- and post-testing instruments. Each assessment will take 20 minutes of class time each, so a total of 60 minutes over the course of the research project.
- Administer two 15-minute surveys for students to complete during class time, so a total of 30 minutes.
- Participate in three semi-structured interviews. These interviews should each last no longer than 20 minutes, so a total of 60 minutes.
- In total, a time commitment of 450 minutes will be required for the abovementioned tasks.

[1] The creation of the flipped learning content is anticipated to be more time consuming than the teacher's regular practice. However, this will contribute towards their professional learning, and they are welcome to seek assistance from Andrew McAlindon where necessary.

Students in the flipped classroom will:

- Complete one pre-test and two post-tests for linear equations, each of which run for 20 minutes, so a total of 60 minutes during class time.
- Participate in two 15-minute online surveys, so a total of 30 minutes.
- Watch an online video of no more than 10-minute duration prior to their mathematics lesson – this will constitute the regular homework for that lesson, so is not an extra time commitment. This time demand is in line with the College handbook homework requirements.
- Those students who opt not to participate in the research project will still participate in all planned lessons, however their data will not be used for this project.

The teacher in the non-flipped classroom will:

- Administer pre- and post-testing instruments. Each assessment will take 20 minutes of class time each, so a total of 60 minutes over the course of the research project.
- Administer two 15-minute surveys for students to complete during class time, so a total of 30 minutes.
- In total, a time commitment of 90 minutes will be required for the abovementioned tasks.

Students in the non-flipped classroom will:

- Complete one pre-test and two post-tests for linear equations, each of which run for 20 minutes, so a total of 60 minutes during class time.
- Participate in two 15-minute online surveys, so a total of 30 minutes.
- Those students who opt not to participate in the research project will still participate in all planned lessons, however their data will not be used for this project.

The students in the research project will have a dependent relationship with their classroom teacher. However, the students' involvement within the research project will have no bearing on their final mark and there is no disadvantage for them opting to not be a part of this research project.

The teacher/s in the research project will have a dependent relationship with Andrew McAlindon as the Learning Area Leader for Mathematics. Their participation is entirely voluntary and they can opt not to participate, or withdraw at any time without consequence.

Participation of the teachers and students will be subject to their written consent, and the written consent of the students' parents or guardians. Students in the project classes who elect not to provide data for the project may still participate in these classes as normal, but we will not collect any data from them.

We intend to protect the anonymity and the confidentiality of the participants to the fullest possible extent, within the limits of the law. Participants' names and contact details, as well as collected data will be kept on password-protected computers. In publications following the project, participants will be referred to by a pseudonym. We will remove any references to personal information that might allow someone to guess the participants' identity; however, you should note that as the number of schools involved in this project is small, it is possible that someone may still be able to identify individual participants. All data collected in this project will be kept securely on password protected computers for five years from the date of final publication, before being destroyed.

If you wish, you can indicate on the consent form to have a short summary of the findings emailed to you once the thesis is completed. The results may also be presented at academic conferences, teacher conferences, seminars and in publications such as journal articles, reports, conference papers and book chapters.

Please be advised that the participation of your school, teachers and students in this project is completely voluntary. Should your school wish to withdraw at any stage, or to withdraw any unprocessed data, you are free to do so without prejudice.

If you consent to your school participating in this project, please indicate that you have read and understood this information by signing the accompanying consent form and returning it in the envelope provided.

Should you require any further information, or have any concerns, please do not hesitate to contact Andrew McAlindon on [redacted]

If you have any concerns or complaints about the conduct of this research project, which you do not wish to discuss with the research team, you should contact the Manager, Human Research Ethics, Office for Research Ethics and Integrity, University of Melbourne, VIC 3010. Tel: +61 3 8344 2073 or Fax: +61 3 9347 6739 or Email: HumanEthics-complaints@unimelb.edu.au. All complaints will be treated confidentially. In any correspondence please provide the name of the research team or the name or ethics ID number of the research project.

Yours sincerely,

Andrew McAlindon Lynda Ball Shanton Chang

Principal Consent Form

***Project:* The Effect of a Flipped Classroom Approach on Student Perception and Achievement in Linear Equations.**

Name of School: [redacted]

Name of investigators: Mr Andrew McAlindon, Dr Lynda Ball and Assoc. Prof. Shanton Chang

1. I provide consent for [redacted] to participate in this project, the details of which have been explained to me, and I have been provided with a written plain language statement to keep.
2. I understand that after I sign and return this consent form it will be retained by the researchers.
3. I understand that [redacted] participation will involve up to 2 teachers and the students from their Year 9 mathematics classes, and that the participation of these teachers and students is voluntary.
4. I acknowledge that:

   (a) the possible effects of participating in this project have been explained to my satisfaction;

   (b) I have been informed that [redacted] is free to withdraw from the project at any time without explanation or prejudice and to withdraw any unprocessed data the participants have provided;

   (c) the project is for the purpose of research;

   (d) I have been informed that the confidentiality of the participants will be safeguarded subject to any legal requirements;

   (e) [redacted] will be referred to by a pseudonym in any publications arising from the research;

   (f) I have been informed that a copy of the research findings will be forwarded to me, should I agree to this.

I wish to receive a copy of the summary project report on research findings ☐ **yes** ☐ **no**
(please tick)

Principal name:

Principal signature: Date:

Email:
(If you wish to receive a copy of the research findings)

Melbourne Graduate School of Education
Kwong Lee Dow Building, 234 Queensberry Street, The University of Melbourne, Victoria 3010 Australia
Ethics Id. 1750414.1;
Date: ________, Version: 1.4
W: education.unimelb.edu.au | **unimelb.edu.au**

Appendix C. Teacher Participant Plain Language Statement and Consent Form

Teacher Plain Language Statement

Project: ***The Effect of a Flipped Classroom Approach on Student Perception and Achievement in Linear Equations.***

Dear [redacted],

We would like to invite you to participate in the above research project, which is being conducted by Mr Andrew McAlindon (Melbourne Graduate School of Education), Dr Lynda Ball (Melbourne Graduate School of Education), and Assoc. Prof. Shanton Chang (School of Computing and Information Systems). Catholic Education Melbourne and the University of Melbourne Human Research Ethics Committee have approved this project. Your participation in this project is voluntary.

In this project we will compare the impact of two teaching approaches (flipped vs. non-flipped) within a 'linear equations' unit in two Year 9 mathematics classes. We will compare the student understanding of concepts and skills associated with solving linear equations under a flipped approach in your class, to a classroom that is not utilising a 'flipped-classroom' approach to learning. The project will also compare the student perception of mathematics learning within and between each class. The research project will also seek to gain an understanding of your thoughts, as the teacher, when implementing a flipped approach in linear equations.

Should you agree to participate you will be asked to contribute in the following ways:

- Create up to 15 lessons on linear equations using the platform 'EdPuzzle'. Instructions on how to access and use the EdPuzzle platform will be provided by Andrew McAlindon through an initial demonstration. Andrew will also provide ongoing technical assistance throughout the duration of the project, where necessary. You can expect each online lesson to take around twenty minutes to prepare for, so a total of 300 minutes of planning time will be required by you for this unit. Note: this time commitment can be fulfilled as part of your participation in the Professional Learning Community for the Flipped Classroom.
- Administer pre- and post-testing instruments. Each assessment will take 20 minutes of class time each, so a total of 60 minutes over the course of the research project.
- Administer two 15-minute surveys for students to complete during class time, so a total of 30 minutes.
- Participate in three semi-structured interviews with Andrew McAlindon. These interviews should each last no longer than 20 minutes, so a total of 60 minutes.
- In total, a time commitment of 450 minutes will be required for the abovementioned tasks.

Students in your year 9 mathematics class/es will be asked to participate in the project. The students who participate in the project will:

- Complete one pre-test and two post-tests for linear equations, each of which run for 20 minutes, so a total of 60 minutes during class time.

- Participate in two 15-minute online surveys, so a total of 30 minutes.

- Watch an online video of no more than 10-minute duration prior to your mathematics lesson.

Participation of the students will be subject to their written consent, and the written consent of their parents or guardians. Students in the research project classes who elect not to provide data for the project may still participate in these classes as normal, but we will not collect any data from them. We intend to protect the anonymity and the confidentiality of the participants to the fullest possible extent, within the limits of the law. Participants' names and contact details, as well as collected data will be kept on password-protected computers. In publications following the project, participants will be referred to by a pseudonym. We will remove any references to personal information that might allow someone to guess the participants' identity; however, you should note that as the number of schools involved in this project is small, it is possible that someone may still be able to identify individual participants. All data collected in this project will be kept securely a password-protected computer for five years from the date of thesis publication, before being destroyed.

If you wish, you can indicate on the consent form to have a short summary of the findings emailed to you once the thesis has been completed. The results may also be presented at academic conferences, teacher conferences and seminars and in publications such as journal articles, reports, conference papers and book chapters. Please be advised that your participation in this research project is completely voluntary. Should you wish to withdraw at any stage, or to withdraw any unprocessed data, you are free to do so without prejudice.

If you consent to participating in this project, please indicate that you have read and understood this information by signing the accompanying consent form and returning it in the envelope provided. Should you require any further information, or have any concerns, please do not hesitate to contact Mr Andrew McAlindon on [redacted]

If you have any concerns or complaints about the conduct of this research project, which you do not wish to discuss with the research team, you should contact the Manager, Human Research Ethics, Office for Research Ethics and Integrity, University of Melbourne, VIC 3010. Tel: +61 3 8344 2073 or Fax: +61 3 9347 6739 or Email: HumanEthics-complaints@unimelb.edu.au. All complaints will be treated confidentially. In any correspondence please provide the name of the research team or the name or ethics ID number of the research project.

Yours sincerely,
Andrew McAlindon Lynda Ball Shanton Chang

Consent Form

Project: The Effect of a Flipped Classroom Approach on Student Perception and Achievement in Linear Equations.

Name of School: [redacted]

Name of investigators: Mr Andrew McAlindon, Dr Lynda Ball and Assoc. Prof. Shanton Chang

1. I provide my consent to participate in this project, the details of which have been explained to me, and I have been provided with a written plain language statement to keep.

2. I understand that after I sign and return this consent form it will be retained by the researchers.

3. I understand that my participation involves creating online material for students to access, along with administering pre- and post-testing and surveys to the students of one of my year 9 mathematics classes. I will also partake in three semi-structure interviews. I understand that my participation in this research is voluntary.

4. I acknowledge that:

   (a) the possible effects of participating in this project have been explained to my satisfaction;

   (b) I have been informed that I am free to withdraw from the project at any time without explanation or prejudice and I am able to withdraw any unprocessed data I have provided;

   (c) the project is for the purpose of research;

   (d) I have been informed that the confidentiality of the participants will be safeguarded subject to any legal requirements;

   (e) [redacted], along with all participants of the research project will be referred to by a pseudonym in any publications arising from the research;

   (f) I have been informed that a copy of the research findings will be forwarded to me, should I agree to this.

<u>I wish to receive a copy of the summary project report on research findings</u> □ **yes** □ **no**
(please tick)

Teacher name:

Teacher signature: Date:

Email:
(If you wish to receive a copy of the research findings)

Melbourne Graduate School of Education
Kwong Lee Dow Building, 234 Queensberry Street, The University of Melbourne, Victoria 3010 Australia Ethics Id. 1750414.1;
Date: ________, Version: 1.4
W: education.unimelb.edu.au | **unimelb.edu.au**

Appendix D. Student Participant Plain Language Statement and Consent Form (Flipped Classroom)

Plain Language Statement (Flipped)

Project: The Effect of a Flipped Classroom Approach on Student Perception and Achievement in Linear Equations.

Dear Student,

We would like to invite you to participate in the above research project. The aim of our project is to find out about your experiences of learning linear equations when being taught in a different way (flipped classroom). The flipped classroom is a teaching strategy that allows your teacher to present concepts to you via video, which can be downloaded from the internet or the school server if you do not have internet at home. This allows you to pause, rewind and re-watch your teachers explanations as often as you like. In class there will be more time for you to complete and discuss problems.

This research project is being conducted by Mr Andrew McAlindon (Melbourne Graduate School of Education), Dr Lynda Ball (Melbourne Graduate School of Education), and Assoc. Prof. Shanton Chang (School of Computing and Information Systems).

If you agree to participate in our project, you will be asked to contribute in the following ways. We would ask you to:

- Complete one pre-test and two post-tests for linear equations, each of which run for 20 minutes, so a total of 60 minutes during class time.
- Participate in two 15-minute online surveys, so a total of 30 minutes.
- Watch an online video of no more than 10-minute duration prior to your mathematics lesson – this will constitute your regular homework for that lesson, so this is not an extra time commitment. This time demand is in line with the College handbook homework requirements.

We intend to protect the anonymity and the confidentiality of the participants to the fullest possible extent, within the limits of the law. Participants' names and contact details will be kept in a password-protected computer file separate from any data that participants supply. In publications following the project, participants will be referred to by a pseudonym. We will remove any references to personal information that might allow someone to guess the participants' identity; however, you should note that as the number of schools involved in this project is small, it is possible that someone may still be able to identify individual participants. All data collected in this project will be kept securely in password protected computers for five years from the date of publication, before being destroyed.

If you wish, you can indicate on the consent form to have a short summary of the findings emailed to you once the thesis has been completed. The results may also be presented at academic conferences, teacher conferences and seminars and in publications such as journal articles, reports, conference papers and book chapters.

Your participation in this project is completely voluntary and your participation, or otherwise, in this project will in no way impact your school grades. Should you wish to withdraw at any stage, or to withdraw any unprocessed data you have supplied, you are free to do so without prejudice. If you do not wish to participate in this project, you may still participate in the series of lessons but we will not ask you to complete surveys or provide us with your work.

If you would like to participate, please indicate that you and your parent or guardian have read and understood this information by signing the accompanying consent form and returning it in the envelope provided to [redacted]

This project has been approved by Catholic Education Melbourne, and the University of Melbourne Human Research Ethics Committee, however if you require any further information, or have any concerns, please do not hesitate to contact Mr Andrew McAlindon on [redacted]

If you have any concerns or complaints about the conduct of this research project, which you do not wish to discuss with the research team, you should contact the Manager, Human Research Ethics, Office for Research Ethics and Integrity, University of Melbourne, VIC 3010. Tel: +61 3 8344 2073 or Fax: +61 3 9347 6739 or Email: HumanEthics-complaints@unimelb.edu.au. All complaints will be treated confidentially. In any correspondence please provide the name of the research team or the name or ethics ID number of the research project.

Yours sincerely

Andrew McAlindon   Lynda Ball   Shanton Chang

Flipped Student Consent Form

Project: The Effect of a Flipped Classroom Approach on Student Perception and Achievement in Linear Equations.

Name of School: [redacted]

Name of investigators: Mr Andrew McAlindon, Dr Lynda Ball and Assoc. Prof. Shanton Chang

1. I provide consent to participate in this project, the details of which have been explained to me, and I have been provided with a written plain language statement to keep.

2. I understand that after I sign and return this consent form it will be retained by the researchers.

3. I understand that my participation involves accessing lessons online, along with undertaking pre- and post-testing and two surveys. I understand that my participation in this research is voluntary.

4. I acknowledge that:

   (a) the possible effects of participating in this project have been explained to my satisfaction;

   (b) I have been informed that I am free to withdraw from the project at any time without explanation or prejudice and I am able to withdraw any unprocessed data I have provided;

   (c) the project is for the purpose of research;

   (d) I have been informed that the confidentiality of the participants will be safeguarded subject to any legal requirements;

   (e) [redacted], along with all participants of the research project will be referred to by a pseudonym in any publications arising from the research;

   (f) I have been informed that a copy of the research findings will be forwarded to me, should I agree to this.

I wish to receive a copy of the summary project report on research findings ☐ **yes** ☐ **no**
(please tick)

Student name:

Student signature: Date:

Parent/Guardian name:

Parent/Guardian signature: Date:

Email:
(If you wish to receive a copy of the research findings)

Appendix E. Student Participant Plain Language Statement and Consent Form (Regular Classroom)

Plain Language Statement (Non Flipped)

***Project:* The Effect of a Flipped Classroom Approach on Student Perception and Achievement in Linear Equations.**

Dear Student,

We would like to invite you to participate in the above research project. The aim of our project is to find out about your experiences when learning linear equations.

This research project is being conducted by Mr Andrew McAlindon (Melbourne Graduate School of Education), Dr Lynda Ball (Melbourne Graduate School of Education), and Assoc. Prof. Shanton Chang (School of Computing and Information Systems).

If you agree to participate in our project, you will be asked to contribute in the following ways. We would ask you to:

- Complete one pre-test and two post-tests for linear equations, each of which run for 20 minutes, so a total of 60 minutes during class time.
- Participate in two 15-minute online surveys, so a total of 30 minutes.

We intend to protect the anonymity and the confidentiality of the participants to the fullest possible extent, within the limits of the law. Participants' names and contact details will be kept in a password-protected computer file separate from any data that participants supply. In publications following the project, participants will be referred to by a pseudonym. We will remove any references to personal information that might allow someone to guess the participants' identity; however, you should note that as the number of schools involved in this project is small, it is possible that someone may still be able to identify individual participants. All data collected in this project will be kept securely in password protected computers for five years from the date of publication, before being destroyed.

If you wish, you can indicate on the consent form to have a short summary of the findings emailed to you once the thesis has been completed. The results may also be presented at academic conferences, teacher conferences and seminars and in publications such as journal articles, reports, conference papers and book chapters.

Your participation in this project is completely voluntary and your participation, or otherwise, in this project will in no way impact your school grades. Should you wish to withdraw at any stage, or to withdraw any unprocessed data you have supplied, you are free to do so without prejudice. If you do not wish to participate in this project, you may still participate in the series of lessons but we will not ask you to complete surveys or provide us with your work.

If you would like to participate, please indicate that you and your parent or guardian have read and understood this information by signing the accompanying consent form and returning it in the envelope provided to [redacted]

This project has been approved by Catholic Education Melbourne, and the University of Melbourne Human Research Ethics Committee, however if you require any further information, or have any concerns, please do not hesitate to contact Mr Andrew McAlindon on [redacted]

If you have any concerns or complaints about the conduct of this research project, which you do not wish to discuss with the research team, you should contact the Manager, Human Research Ethics, Office for Research Ethics and Integrity, University of Melbourne, VIC 3010. Tel: +61 3 8344 2073 or Fax: +61 3 9347 6739 or Email: HumanEthics-complaints@unimelb.edu.au. All complaints will be treated confidentially. In any correspondence please provide the name of the research team or the name or ethics ID number of the research project.

Yours sincerely

Andrew McAlindon Lynda Ball Shanton Chang

Non Flipped Consent Form

Project: The Effect of a Flipped Classroom Approach on Student Perception and Achievement in Linear Equations.

Name of School: [redacted]

Name of investigators: Mr Andrew McAlindon, Dr Lynda Ball and Assoc. Prof. Shanton Chang

1. I provide consent to participate in this project, the details of which have been explained to me, and I have been provided with a written plain language statement to keep.

2. I understand that after I sign and return this consent form it will be retained by the researchers.

3. I understand that my participation involves undertaking pre- and post-testing and two surveys. I understand that my participation in this research is voluntary.

4. I acknowledge that:

   (a) the possible effects of participating in this project have been explained to my satisfaction;

   (b) I have been informed that I am free to withdraw from the project at any time without explanation or prejudice and I am able to withdraw any unprocessed data I have provided;

   (c) the project is for the purpose of research;

   (d) I have been informed that the confidentiality of the participants will be safeguarded subject to any legal requirements;

   (e[redacted], along with all participants of the research project will be referred to by a pseudonym in any publications arising from the research;

   (f) I have been informed that a copy of the research findings will be forwarded to me, should I agree to this.

I wish to receive a copy of the summary project report on research findings □ **yes** □ **no**
(please tick)

Student name:

Student signature: Date:

Parent/Guardian name:

Parent/Guardian signature: Date:

Email:
(If you wish to receive a copy of the research findings)

Appendix F. Solving Linear Equations Quiz A

Note. From "Linear Equations—Solving: Quiz A" by K. Stacey et al., 2011a (http://www.smart-quiz.edu.au/teacher). Copyright 2011 by SMART research. Reprinted with permission.

First Website Page of SMART Quiz A

Item ID: 3105

Solve each of the following equations using a pen and paper.
Type your answer to each in the space provided.
A calculator is provided for your use.

$3a + 8 = 23$	$4a + 9 = 37$
so $a =$ 5	so $a =$ 7
$5a + 7 = 15$	$8a + 3 = 16$
so $a =$ 8/5	so $a =$ 13/8

Click here if you need a calculator

Second Website Page of SMART Quiz A

Item ID: 3106

Solve each of the following equations using a pen and paper.
Type your answer to each in the space provided.
A calculator is provided for your use.

$8a + 5 = 3a + 14$	$12a + 2 = 8a + 15$
so $a =$ 9/5	so $a =$ 13/4
$7a - 11 = 2a - 4$	$12 - 11a = 5 - a$
so $a =$ 7/5	so $a =$ 7/10

Click here if you need a calculator

Third Website Page of SMART Quiz A

Item ID: 3107

Solve each of the following equations using a pen and paper.
Type your answer to each in the space provided.
A calculator is provided for your use.

$7a - 2 = 16$

so $a =$ 18/7

$14 - 2a = 8$

so $a =$ 3

$3a + 6 + 2a = 7$

so $a =$ 1/5

$\frac{a + 2}{5} = 3$

so $a =$ 13

$\frac{a}{3} + 1 = 5$

so $a =$ 12

$4(a - 3) = 21$

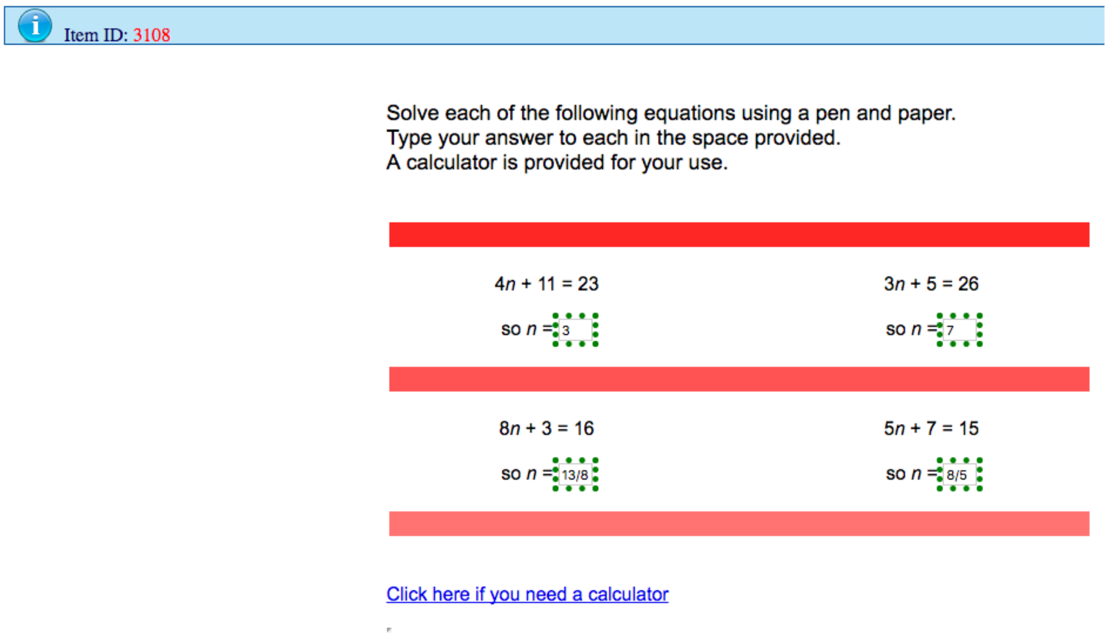
so $a =$ 33/4

Click here if you need a calculator

Appendix G. Solving Linear Equations Quiz B

Note. From "Linear Equations—Solving: Quiz B" by K. Stacey et al., 2011a (http://www.smart-quiz.edu.au/teacher). Copyright 2011 by SMART research. Reprinted with permission.

First Website Page of SMART Quiz B



Second Website Page of SMART Quiz B

Item ID: 3109

Solve each of the following equations using a pen and paper.
Type your answer to each in the space provided.
A calculator is provided for your use.

$11n + 3 = 7n + 16$ so $n =$ 13/4	$9n + 3 = 4n + 12$ so $n =$ 9/5
$7n - 11 = 2n - 4$ so $n =$ 7/5	$12 - 11n = 5 - n$ so $n =$ 7/10

Click here if you need a calculator

Third Website Page of SMART Quiz B

Item ID: 3110

Solve each of the following equations using a pen and paper.
Type your answer to each in the space provided.
A calculator is provided for your use.

$5n - 1 = 16$

so $n =$ 17/5

$15 - 2n = 9$

so $n =$ 3

$2n + 4 + 3n = 5$

so $n =$ 1/5

$\frac{n+1}{5} = 3$

so $n =$ 14

$\frac{n}{4} + 3 = 8$

so $n =$ 20

$5(n - 2) = 8$

so $n =$ 18/5

Click here if you need a calculator

Appendix H. MTAS Survey

Note. Questions and Likert-response are from "A Scale for Monitoring Students' Attitudes to Learning Mathematics With Technology" by R. Pierce et al., 2007, *Computers & Education*, *48*, pp. 299–300. Adapted with permission.

Mathematics & Technology Questionnaire

Please complete the following questionnaire to express your current thoughts and attitudes towards your mathematics learning.

There are no correct or incorrect responses. You are encouraged to select the response that best represents your opinion towards each provided statement.

Your email address ([redacted]) will be recorded when you submit this form. Not [redacted] Sign out

* Required

1. *

Mark only one oval per row.

	Hardly Ever	Occasionally	About Half the Time	Usually	Nearly Always
I concentrate hard in mathematics					
I try to answer questions the teacher asks					
If I make mistakes, I work until I have corrected them					
If I can't do a problem, I keep trying different ideas					

2. *

Mark only one oval per row.

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
I am good at using computers					
I am good at using things like Tablets, Laptops, MP3s and mobile phones					
I can fix a lot of computer problems					
I can master any computer program needed for school					

3. *

Mark only one oval per row.

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
I have a mathematical mind					
I can get good results in mathematics					
I know I can handle difficulties in mathematics					
I am confident with mathematics					

4. *

Mark only one oval per row.

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
I am interested to learn new things in mathematics	◯	◯	◯	◯	◯
In mathematics you get rewards for your effort	◯	◯	◯	◯	◯
Learning mathematics is enjoyable	◯	◯	◯	◯	◯
I get a sense of satisfaction when I solve mathematics problems	◯	◯	◯	◯	◯

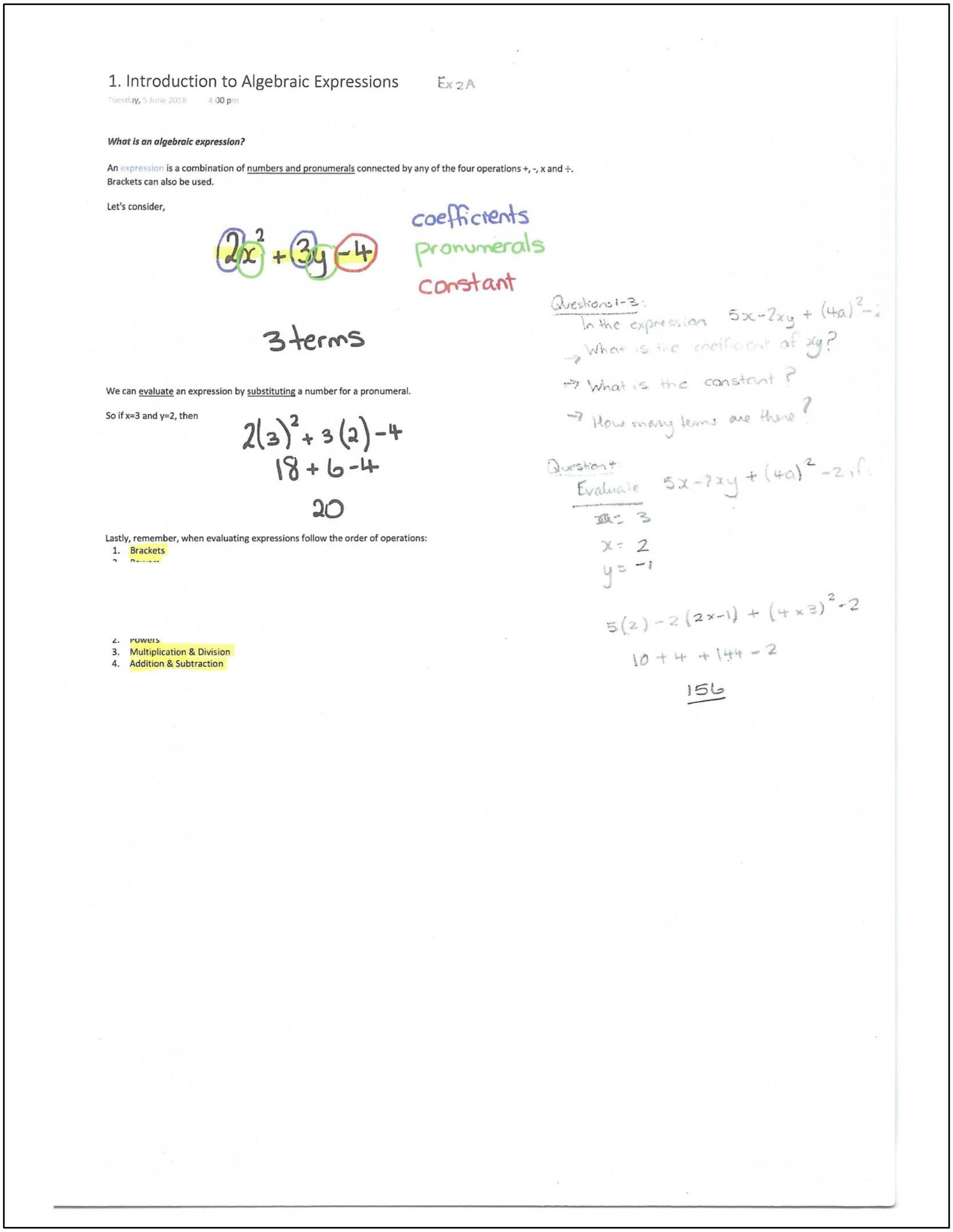
5. *

Mark only one oval per row.

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
I like using the online eBook resource for mathematics	◯	◯	◯	◯	◯
Using computers in mathematics is worth the extra effort	◯	◯	◯	◯	◯
Mathematics is more interesting when using computers	◯	◯	◯	◯	◯
The online resources in the eBook help me learn mathematics better	◯	◯	◯	◯	◯

☐ Send me a copy of my responses.

Appendix I. Lesson Notes and Examples created by the Teacher Participant



1. Introduction to Algebraic Expressions   Ex 2A

Tuesday, 5 June 2018   4:00 pm

What is an algebraic expression?

An expression is a combination of numbers and pronumerals connected by any of the four operations +, -, x and ÷. Brackets can also be used.

Let's consider,

$2x^2 + 3y - 4$

coefficients
pronumerals
constant

3 terms

We can evaluate an expression by substituting a number for a pronumeral.

So if x=3 and y=2, then

$2(3)^2 + 3(2) - 4$

$18 + 6 - 4$

20

Lastly, remember, when evaluating expressions follow the order of operations:

1. Brackets
2. Powers
3. Multiplication & Division
4. Addition & Subtraction

Questions 1-3:

In the expression $5x - 2xy + (4a)^2 - 2$

→ What is the coefficient of xy?

→ What is the constant?

→ How many terms are there?

Question 4:

Evaluate $5x - 2xy + (4a)^2 - 2$, if:

a = 3

x = 2

y = -1

$5(2) - 2(2 \times -1) + (4 \times 3)^2 - 2$

$10 + 4 + 144 - 2$

156

2. Algebraic Expressions Examples

Ex 2A

Tuesday, 5 June 2018 4:01 pm

Example 1: Write an algebraic expression for the following...

A) The sum of a and b $a+b$

B) Ten less than x $x-10$ ~~$10-x$~~

C) The product of x and y $x \times y = xy$

D) The quotient of 4 and a $\frac{4}{a}$

E) Five more than three times a $3a+5$

F) Twice the difference between x and y $2(x-y)$

G) The cost of S sandwiches at \$3 each and D drinks at \$2 each $3S + 2D$

H) Half the product of m and n $\frac{m \times n}{2} = \frac{mn}{2}$

→ Question1: Write an algebraic expression for five times y minus half of x

$5y - \frac{x}{2}$

Example 2: Evaluate these expressions by substituting...

A) $\frac{3x+y}{2}$ if $x = -2$ and $y = 4$

$$\frac{3(-2)+4}{2} = \frac{-6+4}{2} = \frac{-2}{2} = -1$$

B) $a^2 - 2bc$ if $a = -3, b = 2$ and $c = -1$

$$(-3)^2 - 2(2)(-1) = 9 + 4 = 13$$

→ Question2: Find the value of $2(x+3) - 4y$ if $x = -3$ and $y = 3$

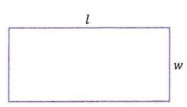
$2(-3+3) - 4(3)$

$2(0) - 12$

$0 - 12$

-12

Example 3: The rectangle below has a length of l and width w.



A) Write an expression for the perimeter of this rectangle.

$$l + l + w + w = 2l + 2w \text{ or } 2(l+w)$$

B) Write an expression for the area of this rectangle.

$$l \times w = lw$$

→ Question3: Write a simplified expression for the perimeter of a triangle with sides a, 2a and 3a.

$6a$

What is the perimeter if $a = 10$cm

$6 \times 10 = 60$cm

C) Use the expressions in part A) and B) to find the perimeter and area of the rectangle if l is 8.2cm and w is 6.3cm.

3. Simplifying algebraic expressions

Ex 2B

Tuesday, 5 June 2018 4:00 pm

- Like terms have the same pronumerals with the same powers.
  Examples:

  $2x$ and $-3x$

  $3a^2b$ and $2ba^2$

Note: $-2x^2y$ and $5xy^2$ are NOT like terms

When **simplifying algebraic expressions**:

- Like terms can be added or subtracted
- Numbers and pronumerals can be multiplied (multiplication symbol is removed)
- Common factors are cancelled when dividing.

Example 1: Simplify the following expressions...

A) $2x + 4y + x =$ $3x + 4y$

B) $5nm^2 - 2nm^2 - 3 =$ $3nm^2 - 3$

C) $3ab - 4 + 4ba - 5 =$ $7ab - 9$

D) $2 \times 5x =$ $10x$

E) $-3a \times 4ab =$ $-12a^2b$

F) $5n \times (-2m) \times 3 =$ $-30nm$

G) $\frac{5xy}{10y} =$ $\frac{5 \times x \times y}{10 \times y} = \frac{x}{2}$

H) $16a^2b \div (-8a) =$ $\frac{16a^2b}{-8a} = -2ab$

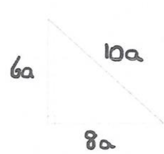
I) $\frac{9m^2n}{18n} =$ $\frac{9 \times m \times m \times n}{18 \times n} = \frac{m^2}{2}$

Question 1: Simplify $2xy^2 - 3x + 4xy^2 + x$
$6xy^2 - 2x$

Question 2: Simplify $-2xy \times (-3x)$
$6x^2y$

Question 3: Simplify $12a^2b \div (-3a)$
$-4ab$

Example 2: The right-angled triangle below has side lengths $6a$ cm, $8a$ cm and $10a$ cm.



Write a simplified expression for:

A) The perimeter of the triangle.

$6a + 8a + 10a$

$P = 24a$ cm

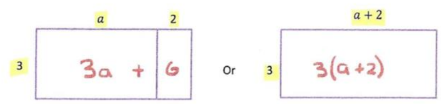
Question 4: A rectangle's length is double its width x mm. Write an expression for the rectangle's perimeter and area.

$P = 6x$

4. Simplifying algebraic expressions (involving brackets) Ex 2C

Tuesday, 5 June 2018 4:01 pm

Let's consider the Area of this rectangle...



3a + 6 = 3(a+2)

This is called the distributive law.

i.e. 3(a+2) = 3a+6

In general:

$$a(b+c) = ab + ac$$
$$a(b-c) = ab - ac$$
$$-a(b+c) = -ab - ac$$
$$-a(b-c) = -ab + ac$$

Example 1: Expand

A) $2(x+3) =$ 2x + 6

B) $4(a-10) =$ 4a − 40

C) $-3(x+5) =$ −3x − 15

D) $-(t-2) =$ −t + 2

E) $6(a+4b) =$ 6a + 24b

F) $-2x(3x-1) =$ $-6x^2 + 2x$

G) $5x(1-2y) =$ 5x − 10xy

Question: Expand $-3a(2a+1)$

$-6a^2 - 3a$

Example 2: Expand and simplify by collecting like terms.

A) $3 + 2(a-4) =$ 3 + 2a − 8
= −5 + 2a

B) $3(x+3) - 5 =$ 3x + 9 − 5
= 3x + 4

C) $1 - (a+3) =$ 1 − a − 3
= −2 − a

D) $2(a-4) + 3(a-6) =$ 2a − 8 + 3a − 18
= 5a − 26

E) $-4(x+2) - 2(1-x) =$ −4x − 8 − 2 + 2x
= −2x − 10

Question 2: Expand $3(x-4) - (2x+3)$

3x − 12 − 2x − 3

x − 15

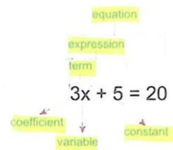
5. Solving linear equations Part A (Ex 2D)

Tuesday, 5 June 2018 4:01 pm

What is an equation?

An equation is a mathematical statement containing an equal sign, where the left-hand side is equal to the right-hand side.

E.g.



$x = 5$

An equation can be solved to find the value of the unknown by using inverse operations:

- Adding or subtracting the same number on both sides
- Multiplying or dividing by the same number on both sides.

To check your solution to an equation, substitute the solution into the original equation and checking that both sides are equal.

Example 1: Solve these one-step equations

A) $x + 8 = 15$ (−8 −8)

$x = 7$ $7 + 8 = 15$ ✓

B) $10 = a - 4$ (+4 +4)

$14 = a$ $14 - 4 = 10$ ✓

$a = 14$

C) $5x = 30$ (÷5 ÷5)

$x = 6$ $5 \times 6 = 30$ ✓

D) $\frac{x}{23} = 6$ (×23 ×23)

$x = 138$ $\frac{138}{23} = 6$ ✓

Question 1: Solve $2x = 20$

$x = 10$

Example 2: Solve these two-step equations

A) $2y + 4 = 12$ (−4 −4)

$\frac{2y}{2} = \frac{8}{2}$ $2(4) + 4 = 12$ ✓

$y = 4$

B) $6 - x = 8$ (−6 −6)

$-x = 2$

6. Solving linear equations Part B (Ex 2D)

Tuesday, 5 June 2018 4:11 pm

Further examples: Solving multi-step equations

1) $\frac{2x}{3} + 8 = 10$

$\frac{2x}{3} = 2$

$\frac{2x}{2} = \frac{6}{2}$

$x = 3$

2) $-\frac{3x}{10} = \frac{1}{5}$

$\frac{-15x}{-15} = \frac{-10}{-15}$

$x = \frac{2}{3}$

3) $\frac{z+1}{4} = \frac{8}{1}$

$z + 1 = 32$

$z = 31$

4) $\frac{-5x-3}{9} = \frac{3}{1}$

$-5x - 3 = 27$

$\frac{-5x}{-5} = \frac{30}{-5}$

$x = -6$

Question 1: Solve $3 - \frac{4z}{3} = 5$

$-\frac{4z}{3} = 2$

$\frac{-4z}{-4} = \frac{6}{-4}$

$z = -3/2$

Question 2: Solve $\frac{2n}{3} = -\frac{4}{5}$

$\frac{10n}{10} = \frac{-12}{10}$

$n = -6/5$

Question 3: Solve $\frac{2x+2}{3} = 4$

$2x + 2 = 12$

$\frac{2x}{2} = \frac{10}{2}$

$x = 5$

Problem-solving question:

Three is subtracted from x and the result is divided by 12 to give 25. Write an equation to represent this statement and solve for x.

$\frac{x-3}{12} = \frac{25}{1}$

$x - 3 = 300$

$x = 303$

Question 4: Sam works 5 hours a week and spends $50 a week. He is left with $80 to save. How much is he paid an hour?

$5x - 50 = 80$

$\frac{5x}{5} = \frac{130}{5}$

$x = \$26$

7. Solving arithmetical linear equations (involving brackets) Ex 2E

Tuesday, 5 June 2018 4:12 pm

Equations with brackets can be solved by firstly expanding the brackets.

Example 1: Solve these linear equations

A) $7(x-5)=28$

$7x-35=28$

$7x=63$

$x=9$

Check: $7(9-5)=28$

Method ②: $\frac{7(x-5)}{7}=\frac{28}{7}$

$x-5=4$

$x=9$

B) $-10(a+1)=5$

$-10a-10=5$

$\frac{-10a}{-10}=\frac{15}{-10}$

$a=-1.5$

C) $3(x+2)+5x=46$

$3x+6+5x=46$

$8x+6=46$

$\frac{8x}{8}=\frac{40}{8}$

$x=5$

Example 2: Five times the sum of 4 and a number is equal to 35. What is the number?

Let x be the number:

$5(4+x)=35$

$20+5x=35$

$\frac{5x}{5}=\frac{15}{5}$

$x=3$

Ans: The unknown number is 3

Question 1: Solve $5+2(x-1)=7$

$5+2x-2=7$

$2x+3=7$

$\frac{2x}{2}=\frac{4}{2}$

$x=2$

Question 2: Solve $2(x+1)-3(x-2)=8$

$2x+2-3x+6=8$

$-x+8=8$

$-x=0$

$x=0$

Question 3: When 5 more than 3 lots of a number is tripled the result is 10. What is the number?

~~$3(2x+5)=10$~~

~~$6x+15=10$~~

~~$\frac{6x}{6}=\frac{-5}{6}$~~

~~$x=-5/6$~~

$3(3x+5)=10$

$9x+15=10$

$\frac{9x}{9}=\frac{-5}{9}$

$x=-5/9$

8. Solving non-arithmetical linear equations

Ex 2E

When an equation has pronumerals on both sides:

- Expand brackets first (if any)
- Collect like terms to one side by adding or subtracting.

Example 1: Solve these linear equations

A) $5y = 3y + 3$

$2y = 3$

$\frac{2y}{2} = \frac{3}{2}$

$y = \frac{3}{2}$ or 1.5

B) $7x + 5 = 2 - 4x$

$11x + 5 = 2$

$\frac{11x}{11} = \frac{-3}{11}$

$x = \frac{-3}{11}$

Question: Solve $3a + 6 = 2 - a$

$4a + 6 = 2$

$\frac{4a}{4} = \frac{-4}{4}$

$a = -1$

C) $3(x + 1) = 14 - 2x$

$3x + 3 = 14 - 2x$

$5x + 3 = 14$

$\frac{5x}{5} = \frac{11}{5}$

$x = \frac{11}{5}$

D) $2(x + 3) = 3(x + 7)$

$2x + 6 = 3x + 21$

$6 = x + 21$

$-15 = x$

$x = -15$

Question 2: Solve $3(x+4) = -2(3x+2)$

$3x + 12 = -6x - 4$

$9x + 12 = -4$

$\frac{9x}{9} = \frac{-16}{9}$

$x = \frac{-16}{9}$

Example 2: If you multiply an unknown number by 6 and then add 5, the result is 7 less than the unknown number plus 1 multiplied by 3. Find the unknown number.

Let x be the unknown number:

$6x + 5 = 3(x + 1) - 7$

$6x + 5 = 3x + 3 - 7$

$6x + 5 = 3x - 4$

$3x + 5 = -4$

$\frac{3x}{3} = \frac{-9}{3}$

$x = -3$

Ans: The unknown number is 3.

Question 3: Eight more than a certain number 14 less than three times the same number. Write an equation and solve it to find the number

$x + 8 = 3x - 14$

$8 = 2x - 14$

$\frac{22}{2} = \frac{2x}{2}$

$11 = x$

9. Solving word problems   Ex 2F

Steps to solve worded problems:

- To solve a **word problem** using algebra:
  - Read the problem and find out what the question is asking for.
  - Define a variable and write a statement such as: 'Let x be the number of ......' The variable is often what you have been asked to find.
  - Write an equation using your defined variable to show the relationship between the facts in the question.
  - Solve the equation.
  - Answer the question in words.

Example 1:

Five less than a certain number is 9 less than three times the number. Write an equation and solve it to find the number.

Let x be the number:

$$x - 5 = 3x - 9$$

$$-5 = 2x - 9$$

$$\frac{4}{2} = \frac{2x}{2}$$

$$2 = x$$

Ans: 2 is the unknown number

Q1. Samuel's dad is 11yrs older than twice Samuel's age. If his da[d] is 35yrs old, how old is Sam[uel]

$$2x + 11 = 35$$

$$2x = 24$$

$$x = 12$$

Example 2:

David and Mitch made 254 runs between them in a cricket match. If Mitch made 68 more runs than David, how many runs did each of them make?

Let r be the number of runs for David

Mitch $= r + 68$

David $= r$

$$r + (r + 68) = 254$$

$$2r + 68 = 254$$

$$\frac{2r}{2} = \frac{186}{2}$$

$$r = 93$$

Ans: David has 93 runs

Mitch has 93 + 68 = 161 runs

Example 3:

Taxi charges are $3.60 plus $1.38 per kilometre for any trip in Melbourne. If Elena's taxi fare was $38.10, how far did she travel?

Let x be the distance (km) travelled:

Q2: Andrew, Bianca and Chin have 351 stamps altogether. Andrew has 25 more stamps than Bianca, and Chin h[as] twice as many stamps as Andrew and Bianca combined. How many stamps does each person have?

*

10. Transposing linear formulae Part A

Ex2H

- A formula is an equation that relates to two or more pronumerals.
- A variable in a formula can be evaluated by substituting numbers for all other variables.
- When rearranging formulae, the same methods as for solving linear equations is used.
- The subject of the formula is the pronumeral that is written by itself, usually on the left hand side of the equation.

Example: $C = 2\pi r$ where C is the subject of the formula.

$\frac{C}{2\pi} = r$

$r = \frac{C}{2\pi}$ so now, r is the subject of the formula.

Substituting into formulae:

1. Evaluate $S = \frac{a}{1-r}$, when $a = 3$ and $r = 0.4$

$S = \frac{3}{1-0.4}$

$S = 5$

2. Evaluate $E = \frac{1}{2}mv^2$, when $m = 4$ and $v = 5$

$E = \frac{mv^2}{2}$

$E = \frac{4 \times 5^2}{2}$

$E = 50$

Question 1: Evaluate $x = ut + \frac{1}{2}at^2$ when $u = 0$, $t = 4$, $a = 10$

$x = 80$

3. The area of a trapezium is given by $A = \frac{1}{2}(a+b)h$. Substitute $A = 12$, $a = 5$ and $h = 4$ then find the value of b.

$A = \frac{h}{2}(a+b)$

$12 = \frac{4}{2}(5+b)$

$\frac{12}{2} = \frac{2(5+b)}{2}$

$-5 \quad -5$

Question 2: Evaluate $v^2 = u^2 + 2as$ if $v = 22$, $u = 6$ and $a = 12$

$S = 18.67$

11. Transposing linear formulae Part B   Ex 2H

- A formula can be transposed (rearranged) to make another variable the subject.
- To transpose a formula use similar steps as you would for solving an equation.

Transposing formulae examples:

1) Make b the subject of the formula $c = a(x + b)$

$\frac{c}{a} = x + b$

$\frac{c}{a} - x = b$

$b = \frac{c}{a} - x$

2) Make v the subject of the formula $a = \frac{v - u}{t}$

$at = v - u$

$at + u = v$

$v = at + u$

Q1: Make x the subject of the formula $p(x+q) = m$

$x = \frac{m}{p} - q$

3) Make b the subject of the formula

$c = \sqrt{a^2 + b^2}$ $(b > 0)$

$c^2 = a^2 + b^2$

$\sqrt{c^2 - a^2} = \sqrt{b^2}$

$\sqrt{c^2 - a^2} = b$

$b = \sqrt{c^2 - a^2}$

4) Make c the subject of the formula $d = b^2 - 4ac$

$d - b^2 = -4ac$

$\frac{d - b^2}{-4a} = c$

$c = \frac{d - b^2}{-4a}$

Q2: Make p the subject of the formula $\frac{px}{q} + s = t$

$p = \frac{q(t-s)}{x}$

5) Make x the subject of the formula $6(y + 1) = 7(x - 2)$

$6y + 6 = 7x - 14$

$\frac{6y + 20}{7} = \frac{7x}{7}$

$\frac{6y + 20}{7} = x$

$x = \frac{6y + 20}{7}$

6) Make y the subject of the formula $m = \frac{y - a}{x - b}$

$m(x - b) = y - a$

$m(x - b) + a = y$

$y = m(x - b) + a$

or

$y = mx - mb + a$

Q3: Make x the subject of the formula $\frac{nx - m}{m} = p$

$x = \frac{nm + m}{n}$

Appendix J. Duration of Video Tutorials for Each Lesson

Lesson	Lesson Title	Content Focus	Flipped Video Duration (mins:sec)
1	Linear Equations Pre-Test	• Previous Topic Reflection • Pre-Topic Student Attitude Survey • Linear Equations Pre-Test (Quiz A) • Setup Transition to Flipped Classroom (for Flipped Cohort)	N/A
2	Consolidating Algebraic Expressions (Part A)	• Consolidating Algebraic Expressions (2A)	2:09
3	Consolidating Algebraic Expressions (Part B)	• Consolidating Algebraic Expressions (2A)	6:12
4	Simplifying Algebraic Expressions	• Consolidating Simplification of Algebraic Expressions (2B)	6:54
5	Simplifying Algebraic Expressions (with Brackets)	• Consolidating Simplification of Algebraic Expressions involving brackets (2C)	10:36
6	Solving Linear Equations (Part A)	• Solving arithmetical linear equations (2D)	6:55
7	Solving Linear Equations (Part B)	• Solving arithmetical linear equations (2D)	5:14
8	Solving Arithmetical Linear Equations involving Brackets	• Solving arithmetical linear equations involving brackets (2E)	5:55
9	Solving Non-Arithmetical Linear Equations involving Brackets (Part A)	• Solving non-arithmetical linear equations involving brackets (2E)	7:50
10	Solving Non-Arithmetical Linear Equations involving Brackets (Part B)	• Solving non-arithmetical linear equations involving brackets (2E)	SAME VIDEO AS PART A (ABOVE)

11	Solving Linear Equations with Worded Problems (Part A)	• Solving with worded problems	9:58
12	Solving Linear Equations with Worded Problems (Part B)	• Solving with worded problems	SAME VIDEO AS PART A (ABOVE)
13	Transposing Linear Formulae (Part A)	• Transposing linear formulae (2H)	4:50
14	Transposing Linear Formulae (Part B)	• Transposing linear formulae (2H)	7:15
15	Review of Content	• Review of content	NO SPECIFIC VIDEO ASSIGNED
16	Linear Equations Post Test	• Linear Equations Post-Test (Quiz B) • Post-Topic Student Attitude Survey	N/A

Appendix K. Edpuzzle Extract of Student Viewing Time

Student #	Time Report By EdPuzzle	Viewing Time Range
1	1 hour	60 – 119 minutes
2	1 hour	60 – 119 minutes
3	1 hour	60 – 119 minutes
4	1 hour	60 – 119 minutes
5	1 hour	60 – 119 minutes
6	1 hour	60 – 119 minutes
7	1 hour	60 – 119 minutes
8	49 minutes	49 minutes
9	1 hour	60 – 119 minutes
10	2 hours	120 – 179 minutes
11	1 hour	60 – 119 minutes
12	1 hour	60 – 119 minutes
13	1 hour	60 – 119 minutes
14	8 minutes	8 minutes
15	1 hour	60 – 119 minutes
16	1 hour	60 – 119 minutes
17	1 hour	60 – 119 minutes
18	2 hours	120 – 179 minutes
19	1 hour	60 – 119 minutes
20	1 hour	60 – 119 minutes
21	1 hour	60 – 119 minutes
22	1 hour	60 – 119 minutes

Appendix L. Semistructured Interview Questions and Rationale

First Interview: Before starting the Flipped Classroom with Students:

Question / Prompt	Intention / Rationale
Describe your usual preparation for a linear equations lesson, in terms of time and resources. - Average time planning for a 50 minute lesson - Typical resources used (i.e. MacBooks – in what way?)	Gain an understanding of time commitments in planning for a usual lesson – including the standard used resources. Need this as a reference point for discussions around workload and potential differences in preparation/resources in a flipped approach.
Describe your usual teaching practice in the mathematics classroom, in terms of whiteboard use and questioning. - How do you usually 'teach' concepts within linear equations? - How do you know when students are understanding what you are teaching?	Gain an understanding on the way the board is used to convey examples / content. Gain an understanding of how questioning may or may not currently play a role in this teachers practice (i.e. on going formative practices). Need this as a reference point for discussions of content delivery and formative assessment strategies inherent in a flipped approach.
Discuss your current experiences and comfort with technology. - How does this comfort level usually play out in your mathematics classes? - How does it usually play out in your preparation of these classes, specifically, previous linear units?	Gain an understanding of their current familiarity and comfort with technology. Try to understand if this will be a barrier or influencing factor in the way the teacher interacts within the flipped classroom (content creation / student monitoring). Can return to these items throughout the discussion as influencing factors.
Describe your preparation for the linear lessons for the flipped classroom group. In doing this, detail your experience in creating the content using technology, including the upload of this to content EdPuzzle. Factors to prompt- did you find anything particularly easy/straight forward? Anything particularly difficult? Anything	Knowing this teacher has made all videos prior to the topic starting – wanting to gain an understanding of the teachers experiences in creating each video, including any factors that may have contributed to difficulties throughout the creation process.

you ended up abandoning as a result of its difficulty? How do you feel the flipped approach aligns with your usual teaching methodology? Discuss any similarities and differences.	Wanting to gain an understanding of the effort required to upload all content to the EdPuzzle platform. Gives insight into the teacher's current thoughts towards flipped learning and the place for it in their teaching strategies/approaches – can return to the points made here in later interviews.
In your previous experiences, how have you found students to perform and perceive linear equations in your usual teaching format? Do you anticipate any differences with the flipped approach, in terms of student understanding or engagement? Why / why not?	Gives a baseline reference point to inform future rounds of questioning (i.e. an understanding if a flipped classroom falls short / meets / exceeds previous experiences). Highlights what they anticipate a flipped approach could bring about – providing a reference for future interviews.
Was there a reason you selected one particular group to receive the flipped instruction over the other? If so, can you elaborate further on this in terms of your expectations?	Try and ascertain if the teacher believes a certain cohort may benefit more from a flipped approach – and if so, why. Can return to this point in future interviews.

Second Interview: During (Mid-way) Implementation of the Flipped Classroom:

Question / Prompt	Intention / Rationale
How did you establish the expectations around the flipped classroom for your flipped students? What have you found students have taken well to with the flipped classroom? What have the students struggled with?	Gain insight on how it was 'rolled out' to students. The ground rules that were put in place for accessing content. Provide insight into how the students interpreted this instruction and what they did with it – positive or negative. Will provide insight into the ease with which a flipped approach can be utilised in a secondary classroom.
Tell me about the differences and similarities between that you have seen in your flipped and non-flipped classrooms. Have you had to address any of these issues with students?	Gives a sense of whether or not the teacher is aware of any differences and how/if they may have addressed these. Also gives an opportunity to reference to the first round of questions – things the teacher may have anticipated as being similar or different.

Have you noticed any obvious differences between engagement or understanding between the flipped and non-flipped groups as a whole? Describe the difference. Any differences between groups of students within each group? Describe the difference.	
Did the students have any technical difficulties? How do you think the students are finding the flipped classroom approach to learning linear equations?	Want to be able to gain an understanding of any difficulties that may have impacted the results. Provides more data on the student attitudes towards a flipped approach (from the teacher perspective).
Do you check how often students have completed their work in both classes? How do you do this for each class? Do you know when students are accessing the flipped content (i.e. Home, train, bus?)?	Insight into how/if the teacher is able to easily check work in both classroom environments. Gain further insight into the obtained results – students who access content in different environments (i.e. noisy v.s. quiet) could have results that have been influenced by their environment – would be good to be aware of this.
Have you adjusted/refined any of your face-to-face content based on the flipped student responses to your questions in EdPuzzle? Has anything been surprising in the student responses to your EdPuzzle questions?	Get an understanding of the implications of what would not be so obvious to the teacher without a flipped approach (i.e. the impact of the formative assessment side of the flipped approach).
Other prompts to ensure reference to any themes that may have arisen from the first interview Did you have any technical difficulties? Any unexpected benefits or draw backs? Anything different in interactions between student student or student teacher?	Provide an opportunity to return to any themes that may have arisen during the first interview that have not had the chance to be addressed through the above prompts.

Third Interview: After Completion of the Flipped Classroom:

Question / Prompt	Intention / Rationale
Can you describe how you found the implementation of the flipped classroom compared to your regular approach. Do you feel any groups of students were able to benefit more from any one type of approach (i.e. flipped or non-flipped)? What makes you think this? Do you feel any groups of students were at any more of a disadvantage in any of the approaches? What makes you think this? You mentioned in the last interview about a student who you thought wouldn't get Algebra, can you explain their journey a little more and how this was turned out different to your expectations? Mention student name of struggling kid. What did the flipped students struggle more or less with when compared to the other class?	Gain an overall on-balance look at what the teacher found in their implementation of a new teaching approach. Gain an insight into what the teacher believes to be the benefits or drawbacks of particular approaches and why.
When you are walking around the classroom, what is your perception of what is going on? What would be an outsider's perspective on what is happening if they were to walk into each class? Did students in the flipped vs non-flipped have different types of problems?	Opportunity to gain insight on perspective of how the class runs. Without the use of observations, provides the opportunity to have the teacher reflect what an outside observer may see – providing detailed accounts of the dynamics of the class.
Can you discuss the workload requirements to produce your flipped lessons, and compare this to your regular approach? Do you believe the additional workload is worth the effort in the long run? Why or why not?	Have an adequate reference point between workload in the flipped vs regular classroom. Gain an understanding if any workload imbalances are worth the trouble and why they believe this to be the case.

On balance, how do you see the future of the flipped classroom in your future mathematics classes? Consider this in reference to your usual approach. Why do you think this?	Gain perspective on the longer term use of the flipped approach and the rationale behind this.
Are there factors that you would consider (i.e. student groups, topics taught, classroom setup, year level) as being conducive to a flipped approach? Discuss these factors and your opinion on why they would influence the success of a flipped approach. What advice would you now offer to anyone wanting to create flipped content for maths?	Gives an opportunity for perspective on specific factors from the teachers point of view that they feel are most conducive to a flipped approach. Returns them to their first round of questioning about things they found easy, difficult – allows for a full circle in terms of discussion and points to a way forward for potential future teachers.
What sort of training and resources do you think teachers need to be successful in flipped lessons? Training, resource, timing. What advice do you think is pivotal for students to have in order to get the most from flipped learning? Draw out themes from previous two interviews.	Opportunities to elaborate further on the themes that arose from the first two interviews. In particular, drawing on aspects on what they had anticipated/expected, and if these eventuated the way they believed they would.

Appendix M. Semistructured Interview 1 Transcript

Researcher and Teacher Participant

R1_01 RESEARCHER: In terms of your usual preparation for linear equations and units that you've, ah, done for that, are you able to just describe how you usually plan for a 50-minute lesson or a 100-minute lesson with linear equations, in your standard way?

T1_01 TEACHER PARTICIPANT: So as individual lessons, I would probably start with reviewing with whatever we would have done in the previous lesson and…. discuss any difficulties, the students would have already corrected their work, and then we just review the… those, common difficulties that they've had, at home. And then we start with the new skill, so we usually discuss it, and then I will write down a summary of notes… any terminology or… any step by step examples, and then followed by….depends… so many examples where students are given the time to work them out, and then we will see what everyone has done and I will ask some students to give me their working out. Errmm, when we are happy, when I'm happy, with what I see that students are quite comfortable with the new skill, then they will start the class work. Sometimes we don't get much class work time in a lesson.

R1_02 RESEARCHER: And then in terms of knowing what to teach, and what skills to focus on, so you rely on the students for that, is there any resources you use to help with that or…?

T1_02 TEACHER PARTICIPANT: So, first of all, it's based on the Victorian Curriculum and then it's Cambridge that we use, as sort of our main resource to get the exercises. But with examples, umm, sometimes I make them up myself, based on what's in the book as well.

R1_03 RESEARCHER: And when the student's are showing you what they are able to do, how…how does that happen? How do they show you what they can do?

T1_03 TEACHER PARTICIPANT: It's… when I'm asking them the questions, so I might break down one, if we are solving an equation, I might break it down into, into steps, and each student is giving me one step, and then I change to another student. So it's more sort of that feedback that I'm getting, umm, that they can work it out. And then, when they're doing the work individually, when I'm going around and I, if I see them stuck, that's when I know that someone needs more help.

R1_04 RESEARCHER: And is there a way that you know, ah, when students are understanding what you've just taught?

T1_04 TEACHER PARTICIPANT: Ummm, as I've said, probably, I mean if they are answering my questions, umm, usually students are quite comfortable in asking me by putting up their hand that they still don't get it, and…cause they know that we will go through other examples or that I'm happy to help them out individually then.

R1_05 RESEARCHER: Yep, and then in terms of, ah, sort of a different side topic here, just your experiences with technology in general and technology in general in the classroom, how have you usually…what's your general comfort level at the moment with using technology?

T1_05 TEACHER PARTICIPANT: So, obviously using the MacBook, the Cambridge and all the resources that come with it. Erm, using the CAS calculator and the emulator on the, on the ahh, on the laptop aswell. Ahhh, as far as finding other resources, you know, finding other websites such as Math Drills or, you know, other eBooks, such as JacPlus.

R1_06 RESEARCHER: Ok, and ahh, with all that considered, how does technology generally play out in the class?

T1_06 TEACHER PARTICIPANT: I think it's… I wouldn't really call it the biggest component of the class. It's mainly our discussion and the examples and… what we are working out, then it is mostly used by the students, umm, when they need to access their exercises. Yeah and when they want to watch their tutorials as well, which I highly recommend for them for them to do at home.

R1_07 RESEARCHER: Yep, and those tutorials...where are they from?

T1_07 TEACHER PARTICIPANT: So they are on the Cambridge, so each chapter has examples, and the examples are tutorials so the students can click on each example and there will be someone talking to them through, through the whole example and they can listen to it.

R1_08 RESEARCHER: And do you know if students use that often, or?

T1_08 TEACHER PARTICIPANT: I don't think they do use it all that often, because…. of the examples we do in class. Umm, when I see them using it most, is when we've got a revision session, and they go ohh miss I forgot how to do this, so they will refer back to the tutorial… before asking me, so sometimes you know, the fact that they can stop the tutorial at any time and follow the steps. To be honest they might be doing it at home, but I wouldn't know. You know, because I tell them, look if you are stuck with these questions, you can refer to the tutorials.

R1_09 RESEARCHER: And so, all of that considered, so that's, you know, the lead up to the classroom and the planning and everything else, how long do you think, ahh, on average it would take you to plan for a standard 50-minute or 100-minute lesson for linear equations?

T1_09 TEACHER PARTICIPANT: Probably because of the experience… not much once I know which skill needs to be, umm, taught in that particular class. Umm, I would just sort of review and have an idea of the examples I am going to do in class and have their homework, know which homework they are going to do… classwork and homework, so…

look, in 5 minutes I can determine what a class is going to do for a 50 minute period. Organising and planning work for students with diverse needs is also quite time consuming.

R1_10 RESEARCHER: Ok, so about five minutes. Ok so then that considered obviously now having a look at some of the flipped content and doing some things with flipped learning, do you want to describe, ahh, your preparation for linear, your linear lessons for the flipped classroom group and, um, just tell me a little bit about your experience in creating that content using the technology and uploading it to EdPuzzle and everything in between

T1_10 TEACHER PARTICIPANT: Definitely more lengthy than the five minutes, um, so, again obviously I broke down, like I would normally do, the topic into lessons, and the skills they would have to do in each lesson, and then I had to write my notes, the ones that I was going to write using one note. Umm, so that took a while, and working out all the examples that I was going to put there, then I had to type them in which requires a little bit more of time. And then, the recording part, is probably the longest, at the start, until I got used to QuickTime player and handling everything with the Intuous and everything. So overall, it's… it's a big job, its much longer than the five minutes that I would prepare for without, without you know the use of, or doing flipped learning

R1_11 RESEARCHER: And umm, was there anything that you found of all of that, you said that it's a little bit more time consuming, was there anything you found particularly difficult or, or….so difficult that you ended up abandoning, did you change strategies at any stage, or?

T1_11 TEACHER PARTICIPANT: Not really, I think ah, just maybe not using the headphones if I was in a quiet place, umm, so that there is no background noise. And I tried to be less perfect, so if a mistake was done I would just say no this is the way it needs to be done, rather than just starting from scratch. Umm… no, it just took some time adjust to that Intuous.

R1_12 RESEARCHER: Yep, and how long did you think it took for you to sort of just accept that there was a mistake in the video or, or in your talking and you would just continue on?

T1_12 TEACHER PARTICIPANT: Oh, look probably after about five lessons I thought, you know what, everybody makes mistakes… sometimes if it was a big one I did re-start though.

R1_13 RESEARCHER: Now that you've created, sort of a whole series of different flipped lessons, in preparation for your linear unit, how do you feel, overall that, ahh, the planning and creation of those lessons and what they're intended to do, how do you feel that aligns with your usual teaching methods?

T1_13 TEACHER PARTICIPANT: So, the students are still going to get the same notes, the same amount of examples that I would normally have given if the class was not flipped, umm…and…the difference is going to be the way, it is going to be delivered. So there's more opportunity for the students to….. for me to repeat the same example more than once, it's by them playing the tutorial more than once, or stopping it wherever they want to.

R1_14 RESEARCHER: Yep, so, apart from the fact that one is recorded and one is essentially live, would you say there were much differences in the way you're teaching the content in terms of how you otherwise would have?

T1_14 TEACHER PARTICIPANT: Ahh no, I was literally speaking the way I would speak in the class. The only difference is that I don't have the students… you know, just saying that, or… stopping me along the way, because they have got a difficulty or a question, or if they don't get something…. sort of, definitely I wouldn't, the same content I wouldn't teach in, what I taught in a flipped learning tutorial, which was…. what, up to 10 minutes… in class usually it takes me, could take me half an hour, and that's because of the students asking questions, that interaction, that discussion, and I'm giving them time to copy notes as well, which can take them…for some takes them longer than others.

R1_15 RESEARCHER: And, ahh are there any sort of, ahh, I guess… previous experiences that you would have that lead you to think one way or the other about how you are anticipating it might go in the flipped classroom versus the non-flipped classroom?

T1_15 TEACHER PARTICIPANT: No, at this stage, I have never, I have always taught sort of the same way. Never adopted the flipped learning as of yet.

R1_16 RESEARCHER: And, do you anticipate that there would be… so now you've got a flipped learning group and you've got a non-flipped learning group…do you anticipate there would be any differences, ahh, in terms of student understanding or student engagement or anything like that in one group versus the other?

T1_16 TEACHER PARTICIPANT: I'm hoping, and that would be sort of a good prize for me after all that time I have spent preparing and planning. I'm hoping that the students, the less confident students, will take, probably, they would be at a more advantage than other quick thinking students, and especially, you know, students with low learning abilities, umm, the fact that they can go home and watch the tutorials as many times as they want to, ummm… compared to the non-flipped class where when they are at home they are working by themselves and the teacher is not there and then they will have to wait until the next lesson to review any difficulties. Whereas the flipped group, umm… they will do that sort of.. they will learn the skill at home, and we will discuss is when they are back and they will have more time to complete the class work or work with my assistance.

R1_17 RESEARCHER: And how do you feel, having not started yet, in terms of delivering that content to the class, how do you feel it will be received on their end?

T1_17 TEACHER PARTICIPANT: Umm, it's going to be interesting. I think the students will, ahh, will be quite open to the new idea. Umm, especially you know, cause I told them of course, that you know in the next lesson its not like whatever you got you got, you got, that's it, we are still going to discuss the skill, its just going to be sort of… shorter… and well look at some problems, and some more worded problems, and they can move on with their work. So hopefully the fact that they can access, whenever they want to, especially when they are then preparing for a test, ohh I can go back and watch TEACHERS NAME tutorial, I think they would appreciate it.

R1_18 RESEARCHER: Ah… and in terms of your selection of groups, um, so ultimately a decision had to be made about who would get the flipped classroom and who would get the non-flipped content, was there any particular reasons why you selected one group to get the flipped and the other not to?

T1_18 TEACHER PARTICIPANT: Umm, probably the, sort of the dynamics of the class, maybe one would have been more receptive than the other one, ummm having said that, if it works, it would be beneficial as well for the other class, cause I've got a few students who are quite low ability students so I'm pretty sure it would be good for them... Ummm, no, not really, you know, just nothing definite, not cause I don't want to do it with the other class or something like that.

R1_19 RESEARCHER: Yep, ok, so in terms of your expectations for each class that they'd be…

T1_19 TEACHER PARTICIPANT: [interrupting] … The same… the same. Yes. So they are going to be taught the same content in different ways, but the expectations at the end are the same, same pre-test same post-test.

R1_20 RESEARCHER: And do you have any sort of pre-conceived plans about what hurdles might be in front of you, in terms of the flipped group or the non-flipped group anything that you are anticipating?

T1_20 TEACHER PARTICIPANT: Who's going to do the best, as a class, you mean?

R1_21 RESEARCHER: Ahh, well yeah, actually that would be interesting as well.

T1_21 TEACHER PARTICIPANT: Umm, I would hope still both. Umm… because I'm still a firm believer of the way I teach, there's advantages in both, and you know, in both, you know in both the way I teach and the flipped learning. I'm just curious to see… I don't know… if it's going to work better for the flipped group than the others, I don't know, I can't tell.

R1_22 RESEARCHER: Yep, wait and see.

T1_22 TEACHER PARTICIPANT: Yes! Wait and see.

R1_23 RESEARCHER: And in terms of, ahh, any difficulties that you might perceive with either group, do you feel, lets say with the flipped group that, ahh, that it would run out seamlessly and everyone would watch the videos and do what they need to do or are you anticipating any issues?

T1_23 TEACHER PARTICIPANT: Umm, no it should run smoothly. All videos are prepared I'm quite sure that the group we are dealing with will go on board with the instructions that I'm going to give them… ummm, there might be a few students who wont actually….watch the tutorial… and I guess they will learn sort of their consequences, yeah, if they don't do it, cause its probably the first time for them as well.

R1_24 RESEARCHER: And is there a process, if they don't watch the video have you thought about, what.. what that student would do?

T1_24 TEACHER PARTICIPANT: Ummm, at this stage, hoping its not too many, umm they would have to watch the tutorial in class, ummm and having said that then they have to do more work… by themselves… at home.

R1_25 RESEARCHER: And, what ways are you looking at, at this stage monitoring, you know who's watching it and who's doing what they need to do, and who's getting it and who's not?

T1_25 TEACHER PARTICIPANT: So, the tutorials at this stage will be on EdPuzzle and through EdPuzzle, umm, using some quiz questions that are along the tutorial itself, so the students will have to answer these questions and then I will get the results and that way I will know they have watched it… and the feedback I get, is what they can answer and what they can't answer, which will be the focus of the next lesson.

R1_26 RESEARCHER: And I suppose, one thing that I'm also interested in, is what you see having now put together the videos and you've spoken about how you've prepared for each of the classes, ahh, what you think the advantages or disadvantageous may be in a flipped approach, so what you may see as maybe being a benefit of that, and having not taught it yet, what you see as potentially being a downside to it, relative to what you've previously done?

T1_26 TEACHER PARTICIPANT: So I'd like to believe that the flipped learning is going to help the student access the examples and the tutorials at any time they want to, and as many times as they want to, especially whilst they are doing their work… I tried to put in every kind of example that is going to be given in the exercise for them to complete, umm, so you know it is given to them step by step so that hopefully, you know, should really work well. Umm, a downfall could be that some student might not do their work, having said that, you know, then if it is something that is recurring, then I just issue a homework notification like we always do cause its their homework and that's what I would normally do… I'm hoping that an advantage is that they would find sitting down at home, listening to the tutorial and taking the notes less daunting than actually doing the exercise itself, because they know we are going to do it in the next lesson and I'm there if they need help…. Ummm, a downfall…. I don't know, is that they waste their time in the class, I'm hoping, you know, that they really do understand that this is the time that we are allowing and any work that is not completed they have to still do, obviously at home, plus watching the new tutorial and getting the notes….Ummm, cant think of anything…. Umm, an advantage is for the low ability students, definitely, the fact that they've got the tutorial and they can stop it whenever they want to….revisit it whenever they want to… if students are away, they just can, they just can look at the tutorial as well, and be up to date with their notes and with the work, so there's a few advantages.

R1_27 RESEARCHER: And you mentioned some things about class time there, which got me thinking, do you expect or do you anticipate any differences in how you will use the class time in the flipped group versus how you might use the class time in the non-flipped group?

T1_27 TEACHER PARTICIPANT: It's going be different because we are going to have less class working time in the non-flipped, because I'm doing, I'm teaching them the skill, and they're copying the notes which sometimes takes quite a big chunk out of the lesson, umm, and so, obviously we will have limited time about how much time they can spend doing the exercise. Whereas with the flipped group its going to be… Ok lets review the skill that you have learnt, umm, lets focus on some real world problems or… some worded problems and then you can move on to do your work.

R1_28 RESEARCHER: Yep, and so I guess overall, and we've sort of touched on it throughout, in terms of, at the start we were sort saying – well you were saying, five minutes roughly thereabouts having had the experience of planning a linear non-flipped unit, and then in terms of from start to finish just to – I know its not going to be perfect, but in terms of a minute wise when you started how long did that take to make a flipped lesson versus when you were more experienced and you had made your twelfth or thirteenth lesson, how long that took.

T1_28 TEACHER PARTICIPANT: The first video probably took me… 2 hours, umm, because I couldn't get everything sort of aligned together, video and pen and everything, and to the last one… I did in, like with the notes ready, yeah, so with the notes ready, and the recording took, umm, the 10 minutes probably, that the video was, what the tutorial went for.

R1_29 RESEARCHER: Ok…and how long did the notes take to write?

T1_30 TEACHER PARTICIPANT: It was more preparing the notes, than typing in the notes. Umm, so preparing the notes ... written … took for sure about two to three hours to prepare for a whole unit.

R1_30 RESEARCHER: Yep, and do you think you would do the same again if you were to prepare next time, or there's some tricks that you've learned along the way?

T1_31 TEACHER PARTICIPANT: Umm… I find that the notes, and the examples are the most important part of the lesson of course. So, at this stage I don't think it's going to take me less time, ummm, because then again, I need to pick the right examples which you know… are going to help them to complete the exercise that they are going to be given….the recording will take less, because now I'm more sort of experienced, but the preparation I think will still take some time….to write the notes.

R1_31 RESEARCHER: Well, in terms of everything that I wanted to cover, that covers it all. Is there anything you wanted to add in terms of the whole preparation journey or things that we have probably not spoken about but are worthwhile hearing about?

T1_32 TEACHER PARTICIPANT: Ummm, if given the time, yeah, cause time is always an issue. Umm, the tutorials are always handy, they are always, you know, there, saved. You can use them year after year, so you really only have to do them once, and then just update them…if they are done the right way… Umm, students from… if I am teaching year 10s and I've got year 9 linear equations tutorials, I can even ask them to watch them even if they are very low, so you know, with a bank of tutorials I am pretty sure they will become very very useful, not just for you know, this year, but for other years.

Appendix N. Semistructured Interview 2

Transcript Researcher and Teacher Participant

R2_01 RESEARCHER: How many lessons have you now taught in the linear equations unit for both classes, ahh, and where approximately does that put you in the unit?

T2_01 TEACHER PARTICIPANT: So, we are currently sort of half way with both classes, they're quite sort of at the same stage… umm, so we currently… we're finishing off the solving component and getting into the worded problems, so, another few lessons and then the linear equations topic will be finished.

R2_02 RESEARCHER: And so, in terms of the flipped classroom, when you initially started that, it may have been a bit of a different teaching approach to what the students were used to. I'm just wondering how did you establish the expectations around the flipped classroom for those students?

T2_02 TEACHER PARTICIPANT: So, I repeated again what the expectations are. Ummm, there were a few students who did not watch the tutorial the first time round, but I must say that, you know, by now all students know what they need to do and they are waiting, they are quite prepared actually for the next lesson…umm, so they just went on board with the whole thing, and… probably even better than me…umm, yeah, so they adjusted to this new way of learning.

R2_03 RESEARCHER: What exactly were those expectations?

T2_03 TEACHER PARTICIPANT: The students were told that prior to the lesson they are to come prepared by having watched and copied the tutorials on their notes from EdPuzzle and completed the quiz questions as they go. They were told to highlight any difficulties encountered so they can get these clarified in class during the next lesson. Students not coming prepared will need to watch the tutorials in class hence will be at a disadvantage because they wouldn't be able to take part in the initial introduction to the lesson and skill/s and have less opportunity to work in class on the exercises after that.

R2_04 RESEARCHER: What makes you think the students went onboard with things better than you?

T2_04 TEACHER PARTICIPANT: On my behalf I wanted to make sure I'm assigning the right tutorials at the right time and I was still learning how to get feedback from EdPuzzle of the student's ongoing progress, whereas I could see the students got adjusted to the Flipped Learning system very easily. The majority were always prepared for the lesson, notes written down, questions to ask highlighted and eagerly ready to start working on the exercise in class.

R2_05 RESEARCHER: And did you pre-empt the students about what they may have needed to do to before the class to prepare, did you give any schedule about how or when to watch the video or?...

T2_05 TEACHER PARTICIPANT: So, I have asked them to watch and… they can watch it and then they can copy the notes down or they can watch it and copy as they go and they can stop it every now and then. Umm… and they complete the quiz questions in their book as well, as further examples….And… umm…. they had to watch it by the night before sort of the next lesson, because when I set it for the same day, some were doing it at 6 o'clock in the morning. Umm.. so, then I discussed it with them and I said no, it needs to do be done the night before the next lesson….so on some occasions they had a weekend to do it, because if I see them on Friday then on Monday they had to do it by Sunday, and sometimes if it's from Monday to Friday they've got some more time to do the tutorials. So they were happy, just you know, this is what I need to do, I watch the tutorials, play them as many times as I want to, copy the notes and then, stop there…. because I am going to work in class.

R2_06 RESEARCHER: OK. And do you think there are anything that the students have struggled with, either initially or ongoing in terms of adapting to that?

T2_06 TEACHER PARTICIPANT: At the start they said my voice was a bit too low, but then I promised them that the next ones were going to be better. I asked them for feedback at the start of every lesson, and they have been 'nah we like them miss', 'we can understand them', 'there's enough examples' and I can tell that because they can then go straight into their work after we've reviewed the quiz questions, umm -- so yeah, the feedback was good.

R2_07 RESEARCHER: Ok, and I suppose just in line with that is there anything else you've found that the students have taken to, ahh, in a good way about the flipped classroom? Is there anything that they've mentioned?

T2_07 TEACHER PARTICIPANT: The fact that they have the time to do their exercises in class and then that they've got help. Whether its each other's help, you know on the same table, or whether its myself… umm, yeah… they, they like the fact that they've got, you know they just put their hand up and there's my help. Whereas if they are at home on their own, they have to wait until the next lesson to get it sorted out.

R2_08 RESEARCHER: And, can you tell me a little bit about the differences and the similarities that you've noticed between what you've seen in your flipped classroom versus what you've seen in your non-flipped classroom, given that they are about at the same point of the unit?

T2_08 TEACHER PARTICIPANT: So…umm, I am noticing with the flipped class…. so, if they have some work that they still need to finish off at home, it's usually very minimal, like most of them finish off all the questions in class, and so because we have discussed all the difficulties, then in the next lesson, we don't have any difficulties to discuss, its straight into the next lesson. Whereas with the non-flipped class there's always that, you know the teaching part, and there's less time to do the exercise in class, so then we have more difficulties to discuss at the start of the next lesson, then we need to do the teaching…then there's even less time to do the exercise, so it's sort of that ongoing struggle with time. In the flipped class, I'm not struggling that much with the time, and the kids see more content…that they know they have the time to practice, and they're getting it… and they're finishing off their work. So they seem happier to do the tutorials at home, than the exercises.

R2_09 RESEARCHER: Ok, and so just in drawing that out a little bit more. Are you noticing any specific differences in the interactions between student and student or student and yourself in those classes?

T2_09 TEACHER PARTICIPANT: Umm, students are helping each other more, I noticed, because obviously they've watched the video -- they've understood it -- and then they might be feeling more comfortable helping out each other. And I have more time to sit with those students who struggle with algebra and I can notice that they are… actually, doing quite well. Which, you know, surprises me because I thought, I have a particular student, I didn't think he would get this type of algebra, and I can sometimes leave him on his own and he's doing it! Whereas, you know, in previous topics he would just stop! Because he doesn't know what to do, so yeah, I think, especially for him, umm, the flipped learning is, I guess he's spending so much time watching the tutorial, and if he doesn't get it, he will replay and replay and replay until he feels content.

R2_10 RESEARCHER: Ahh, and so that's the interaction side of things, I know you haven't done any testing as such yet… or have you done any testing?

T2_10 TEACHER PARTICIPANT: No, apart from the SMART test, the pre-test.

R2_11 RESEARCHER: Ok yep, do you get a feel for perhaps any differences in their understanding, between one group; the flipped group and the non-flipped group, are you getting a feel for any of that?

T2_11 TEACHER PARTICIPANT: Umm… I get a feel more from the flipped group because I'm seeing them doing their work in front of me… and I roam around and say ;is it possible that nobody has any question to ask me?'… so I'm finding that 'yeah we're all good miss'. And whereas with the others because they are doing their work at home, it's always a question of, is anyone helping them, is it, you know are they doing it the right way, are they showing all the working out, and…yeah…so…yeah the flipped one is working better, in that regards.

R2_12 RESEARCHER: And ahh, you've sort of touched on this through an earlier question, but last interview you mentioned that, ahhh, the amount of class time that the students had to complete work was never really enough, and what I'm gathering here is that you're finding more time in the class for the flipped group but not the non-flipped group?

T2_12 TEACHER PARTICIPANT: That's right, so with the flipped group, I would probably say out of a double period we're, maximum spending, 20 minutes If I see that they had difficulties with the quiz questions. Um, whereas with the other class having to go through the difficulties from the last lesson and then through the content and then I would say that maybe they end up with 20 minutes of doing work, so that's a big difference.

R2_13 RESEARCHER: Yep, and have you had any issues with students in either class… particularly I want to focus on the flipped group for the moment. Any issues with students and the way they are completing what's being asked of them, watching the videos..?

T2_13 TEACHER PARTICIPANT: No, no not at all. One girl was away for a few lessons and then yesterday she was in class, and I could tell her, you know, you start from tutorial one and you build up your skills one at a time, even if she doesn't finish by the end of the topic, but that's at least a start. The more she works at home, watching the tutorials the more she can catch up with the work. Umm, yeah, no they've been really good, followed all instructions and it's working really well.

R2_14 RESEARCHER: Ok, and, any technical difficulties or anything of that nature?

T2_14 TEACHER PARTICIPANT: Umm, EdPuzzle, sometimes gives me some trouble. Umm, I've got two students who are coming up twice, and I can't understand why. So, when it gives me the percentage and I look at the totals, somethings wrong. It's like not everyone is doing their work and then I noticed that two students have doubled up. Ummm, yes sometimes I have students say 'Oh miss we completed it yesterday', but on EdPuzzle it is telling me that they completed it on the same morning. So just some little issues, but it's more from my end, but the students haven't said you know, 'I couldn't watch it'. No, no issues at home.

R2_15 RESEARCHER: Yep, so everyone is able to watch it and everyone has the Internet or the means to be able to view that?

T2_15 TEACHER PARTICIPANT: Yes, yes, all of them.

R2_16 RESEARCHER: Now, you've touched on this throughout but it's worthwhile asking as well just to narrow down, how do you think the students are finding the flipped classroom approach to learning linear equations, versus not just the only non-flipped group that you've got this year, but versus perhaps any other year you've taught linear equations?

T2_16 TEACHER PARTICIPANT: I heard a comment, a few comments yesterday, 'Miss how easy is algebra?', and I said 'No it's not easy, it's just because you get it, because you understand it'. Umm, so compared to previous years, compared to the other class, the non-flipped class the feedback I'm getting from these guys is, is great. You know, they're enjoying algebra, they are understanding it and they are able to do even, you know, the complex questions.

R2_17 RESEARCHER: And do you check how often the students have completed their work in both of the classes, so both the flipped and non-flipped?

T2_17 TEACHER PARTICIPANT: So, the flipped I can check between one lesson and another, I have a look at how many have completed it and when, how many completed it at, you know, the last minute, the night before. With the non-flipped, it's the day of the lesson, yeah, it's the when I go around and check whether they have done their homework...yeah, so in the flipped group it also saves me the time, because I can check online before I go to class. Whereas with the non-flipped group I have to go around to each table, to each student, you know, overseeing if they've done all the work.

R2_18 RESEARCHER: Through their workbooks?

T2_18 TEACHER PARTICIPANT: Through their workbooks.

R2_19 RESEARCHER: And the flipped group, how are you checking that work?

T2_19 TEACHER PARTICIPANT: So, if they're doing their exercises in class, that's when I'm going around, and they're working in front of me, and then at the start of the lesson whilst we are discussing 'oh were there any difficulties with watching the tutorials, did you have any trouble, any questions, da-da-da', I'm going around just checking that their notes are in their notebook, which they are, including the quiz questions and examples, yeah there were no issues there.

R2_20 RESEARCHER: Yep, and do you have any idea when the students are accessing the flipped content? So, are they accessing it largely during other class time, or before school or after school, or?

T2_20 TEACHER PARTICIPANT: Mainly after school, however there are still some that would leave it to the night before, not too many, just a small number. The rest, sometimes, you know, sometimes they finish off their work and they are starting the tutorial in class, the next tutorial in class, so you know the students that are quite good with algebra they will move on to the next tutorial, if they finish off their work, yeah, so it's a spread.

R2_21 RESEARCHER: And how readily available are those tutorials, could I watch one for any lesson today? Or can I only see the next lesson a couple of days out?

T2_21 TEACHER PARTICIPANT: You can watch any tutorial any time you want to, they're open, they're still open.

R2_22 RESEARCHER: So every one for the unit is open?

T2_22 TEACHER PARTICIPANT: Yes, well…past assigned tutorials stay open, the upcoming one/s to watch for next lesson are open too, however not any future ones.

R2_23 RESEARCHER: Ah ok, and would you have any idea, ahh, where they're watching the videos? Do you know of any that might be watching it on a bus, or are they doing it at home, or homework club or?

T2_23 TEACHER PARTICIPANT: I haven't asked the question directly, but… I think, from what I've heard of them, is at home, they're watching it at home. Only at the start, when I knew, from EdPuzzle that they were doing it in class, two of them were doing it in another class…. So you know I emailed them and said you know 'you're doing maths in another lesson…', but that stopped! Because they know now that I can monitor when they are watching it.

R2_24 RESEARCHER: And, are you noticing any patterns to the way that the students are viewing it? And are those patterns changing at all? So, for instance, at the start was there a large proportion of students watching it right before class and now they've worked out that they'll get an email and they won't be able to do that. Or, ahh, anything that you might be noticing in terms of a pattern, so you know that this student might do it two days before, and this one does it one day before…

T2_24 TEACHER PARTICIPANT: I haven't noticed a pattern, because it depends as well on when I had their lesson and when I'm seeing them next. So, when it falls on the weekend, many will do it on a Sunday night if I see them on Monday. But when it's during the week, most will do it earlier on, so if it's from Monday to Friday then it's earlier on like a Tuesday or Wednesday.

R2_25 RESEARCHER: And have you adjusted or refined any of your face-to-face teaching content based on some of the responses that you've got through EdPuzzle?

T2_25 TEACHER PARTICIPANT: Yes, so, umm, according to the percentages of correct questions, correct answers in the quiz questions, I will project, I will show them the percentage I will show them you know how many of you got this one incorrect, lets discuss it on the board, and usually they go oh now I know what I did wrong, oh yep. So that's helped.

R2_26 RESEARCHER: And, has any of that been surprising to you? Has there been a question where you thought, oh I through that explanation they would have understood that.

T2_26 TEACHER PARTICIPANT: Ummm, yes. I was expecting them…because the quiz questions would be quite similar to the questions covered in the tutorial, anyway its algebra, so it's a different equation but, you know, the skills are the same. Umm, but they usually do just a silly mistake, so they know what they need to do, just a silly mistake and they get the answer wrong, and because sometimes I have put the answers quite close to each other, like, one with a negative one with a positive, they sometimes even pick the wrong one. Ummm, but at the start most of them were getting them all correct, it's more when it came to the more complex ones with the non-arithmetical and with the brackets, that's where the percentages went lower.

R2_27 RESEARCHER: And did you anticipate that happening?

T2_27 TEACHER PARTICIPANT: Yes.

R2_28 RESEARCHER: I guess, so you've spoken about your technical difficulties, ahh, was there anything else you wanted to elaborate on the technical side of things, anything that has been difficult or easier than anticipated?

T2_28 TEACHER PARTICIPANT: Ummm, of course, it's just a click of a button to assign a tutorial, umm I wasn't able to edit the tutorial once I'd assigned it to the students… so there was one mistake that I did in an answer, and I told them 'ohh I'll fix that', but I can't fix it because it's already assigned, unless I assigned it again. Umm, but no, no major issues really, not from my end, not from the kids end. Apart from time factor, sometimes… I think it's not so accurate, I don't know whether it's because the students don't close EdPuzzle…I don't know, but the time issue.

R2_29 RESEARCHER: And has there been anything that a students responded in your questioning on EdPuzzle that's prompted you to change something that you might do in the non-flipped class, so has there been anything from that that's prompted a teaching moment for the non-flipped class?

T2_29 TEACHER PARTICIPANT: Not really, not really. Because when I prepared the notes I knew the selection of examples and the way the notes were given that, that's what I wanted to do, so not really, no.

R2_30 RESEARCHER: And any unexpected benefits or drawbacks to the process. Initially we had a chat about what you might have expected to come out of the flipped classroom, or not expected, has there been anything that's caught you by surprise, good bad or otherwise?

T2_30 TEACHER PARTICIPANT: Umm…Yes, I must say that going into the flipped class I am less stressed with the fact that I'm not time constrained with, you know, oh we need to get through this, this and this. Umm, so I know, sort of I know what is going to happen in the flipped class… umm, and how much time we are going to have to work on it. Whereas with the other class, because I want to allow them time to work in class it's always sort of a struggle, and then you have the behavioural issues because they've had enough of hearing you…. so going into a flipped class…yes, its surprisingly more relaxing… than going into a non-flipped.. with the…you know, with the time stress.

R2_31 RESEARCHER: And you mentioned behavioural issues, are there differences in behaviours from the flipped and the non-flipped, that you're noticing?

T2_31 TEACHER PARTICIPANT: Yes, because, you know, when they are watching the tutorials they're at home. They usually just do it. When you are doing it in class, you know, and it's getting maybe a little bit too long…. students start getting distracted, one's getting up, the other is, you know, doing something else and there's always some kind of distraction, umm… whereas I guess, when they're doing it at home, on their own, even if they are getting up, they are only distracting themselves, they're not keeping everybody else behind.

R2_32 RESEARCHER: And, you mentioned in the last interview that you might see a use in these tutorials for other year levels, and be able to show them to other year levels, have you had any opportunities to show the tutorials that you've created to any other year levels at this stage?

T2_32 TEACHER PARICIPANT: No, not at this stage. But I'm going to hang onto them of course. And yeah, hopefully they become useful… They have already been useful for those students who weren't there, so I have already sort of, yes within the flipped group at this stage, but I've used them that way, so that they can catch up on the work.

R2_33 RESEARCHER: Well in terms of questions, that's it from my end. Was there anything else that you wanted to add about your experiences?

T2_33 TEACHER PARTICIPANT: Umm, well just before you asked me about the behaviour, and I don't think I finished off that. Yes, the behaviour in the flipped group, I think it has improved -- you know they work straight through then they ask for a break, they come back in and then they keep working. Whereas the other group, there is still that struggle, once you finish off the explanation they want a break, because they've had, you know, almost enough, and then they still need to start working. Yeah, so in the flipped group, the behaviour is much better.

R2_34 RESEARCHER: Whereas beforehand the classes were quite similar, or??

T2_34 TEACHER PARTICIPANT: You would have, you know, a few distractions happening, but not just that, you know, you slow down because someone didn't get it straight away, and then you get others waiting, and then the chatting starts, so it wasn't that bad, but… it stopped all of that.

Appendix O. Semistructured Interview 3 Transcript

Researcher and Teacher Participant

R3_01 RESEARCHER: Can you describe how you found the implementation of the flipped classroom compared to your regular approach?

T3_01 TEACHER PARTICIPANT: So, quite time consuming, umm, in preparation for the unit. However, when the unit was running, umm, I found that the class umm, energy, that you need to give, in classroom, was less, because you are more so helping out individual students rather than, you know, preaching for half an hour...umm, so... it's worth the time spending preparing for the flipped classroom.

R3_02 RESEARCHER: And, now that you've finished the unit with both classes, do you feel that there were any groups of students that were able to benefit more from one type of approach versus the other. So, was one group more receptive to the flip or the non-flip…and sorry what I mean by a group is a sub-pocket of the class, so your higher abilities or..

T3_02 TEACHER PARTICIPANT: The lower ability students benefited more from the flipped learning than possibily the more able ones. Umm, even from the results I could tell that their jump in improvement, you know, using the SMART test, their stage, improved a lot. So whether it was because they could you know, watch the tutorials at their own pace, as many times as they want to. This allowed me to help them more in class.

R3_03 RESEARCHER: And did you feel the same gains with the lower ability students in the non-flipped class?

T3_03 TEACHER PARTICIPANT: No, unfortunately it didn't have that advantage. If they didn't get it in class, they were probably then struggling at home, and I was then needing to help them more in the next lesson. So, I was always sort of working on the skill, on the previous skill, with specific students.

R3_04 RESEARCHER: And the other side of that question is, do you feel any groups of students were at a disadvantage with one mode of learning in reference to the other?

T3_04 TEACHER PARTICIPANT: No, I don't think so. Even from their comments, they've all gained from the videos and the tutorials in flipped learning class.

R3_05 RESEARCHER: And you had a student who you mentioned in the last interview who you thought wouldn't get algebra, can you explain a little bit more about where they ended up at the end with their learning and how that all progressed?

T3_05 TEACHER PARTICIPANT: Yes, so unfortunately, he was away for the post test. However from what I could see him working on, by himself, umm, he was working out equations with pronumerals on both sides quite easily and he was doing all that by himself. Whereas, when he started he just looked at the equation in the SMART test and didn't know, he had no idea, no clue what to do. So surely, I could see him progressing in his Algebra skills.

R3_06 RESEARCHER: And, was there any concepts that the flipped students might have struggled with more than the other group or is that sort of covered by what you've already spoken about?

T3_06 TEACHER PARTICIPANT: Pretty much, no, everything was covered the same with both groups.

R3_07 RESEARCHER: So, there wasn't a particular concept, non-arithmetical equations or anything like that, that the flipped group might have found more difficult or easier versus watching or not watching a video?

T3_07 TEACHER PARTICIPANT: Thinking about it more, when we did the transposing of equations, the flipped group, ummm... I had to go through the tutorial again with them in class, because they got most of the questions, the quiz questions incorrect. And so I gave them, you know, we discussed extra examples on the board, and once I explained it on the board, then they said "oh now I get it". So that was one particular tutorial where the students came back telling me "I didn't understand it", "I didn't understand what to do", but then they got it in class.

R3_08 RESEARCHER: And how did the non-flipped class go with the transposing equations lesson?

T3_08 TEACHER PARTICIPANT: It took me a while. Big chunk of the lesson, but they got it towards the end.

R3_09 RESEARCHER: And when you are walking around the classroom what was your perception of what was going on in the flipped class?

T3_09 TEACHER PARTICIPANT: Working. Just, engaged in their work. They were even helping out each other. And, umm, they just… you know, they just wanted to sit down and do their work knowing that I could help them then and there, rather than them going home and having extra work to do. They wanted to leave just the homework to be watching the tutorials and preparing the notes for the next lesson.

R3_10 RESEARCHER: And then, the perception of the non-flipped class, what was the perception of them as you were walking around?

T3_10 TEACHER PARTICIPANT: Well walking around when it's time for them to start working, they're tired by then, they're tired of it all -- so I had to push them to…to encourage them to use their time more efficiently, the half an hour that's usually left.

R3_11 RESEARCHER: And how much time would they roughly have in the flipped version?

T3_11 TEACHER PARTICIPANT: In the flipped version, easily, out of a double…so out of 100 minutes, maybe we would discuss for the first 15 or 20 minutes, and so the rest of the double is for them to work, yeah, so around 80 or so minutes.

R3_12 RESEARCHER: Now I obviously didn't come into any of your classes, but if an outsider were to come into your flipped classroom and your non-flipped classroom what is it that they might observe? Would there be obvious differences they would see between one classroom and another?

T3_12 TEACHER PARTICIPANT: Possibly that the flipped group were more engaged in their work. They were really, you know, heads down and just completing their work. Umm, whereas with the other class, depends on what time this person walks in…they might walk in when it's the delivery of the lesson, so just me talking… or if it's later on when they're working… the students wouldn't be working as hard as those in the flipped group because they would be visibly tired by then...and, they've been working through so many examples until they get it, so when they get a chance to sit down and do their own work, there's not much attention there...or…focus.

R3_13 RESEARCHER: And did you find, we sort of touched on this with the inverse operations discussion, but did you find the students in the flipped versus the non-flipped to have different types of problems, different things that they each may have found difficult after the instruction?

T3_13 TEACHER PARTICIPANT: Umm…no, not necessarily, not necessarily. Just in that lesson in the transposing formulae that's the one that I could see a little bit of difference between the flipped and the non-flipped.

R3_14 RESEARCHER: Yes, ahh. You've spoken about this in this interview as well as the first interview when we first started talking about workload and requirements and that sort of stuff. Initially, you put a lot of time in developing the notes and preparing the videos, and then there was some time that you spent after that in uploading the videos and writing the quiz questions, is that right?

T3_14 TEACHER PARTICIPANT: Yes, so first I finished all the videos and uploaded them. Then I had added the quiz questions.

R3_15 RESEARCHER: So the on-going work from that first interview, where you had sort of created all the videos, until the last video was uploaded and all quiz questions were completed.. how would you describe the workload required for that compared to your regular approach?

T3_15 TEACHER PARTICIPANT: Umm, once the videos are done, that's the biggest chunk of time that you need to spend to prepare for a flipped class. To put the quiz questions together and then to prepare for any other lessons, I think that's sort of at par. But…recording the tutorials, that's the longest time that is spent to prepare. After that, I think it’s the same, it’s the same amount of time, to prepare the quiz questions and to prepare what lesson is coming up next in the non-flipped, it’s pretty much the same.

R3_16 RESEARCHER: And you’re in the best possible position to comment on it now, because you’ve just spoken about the workload and you’ve just finished the unit. Do you believe the additional workload that you’ve mentioned is worth it in the long run?

T3_16 TEACHER PARTICIPANT: In the long run I do. It depends on the topic as well. Ummm.. the nature of the topic. With this linear algebra it worked, the students were very receptive to it and were engaged with all the tutorials and everything. Ummm, so, yeah I do believe it is worthwhile and in the long run because these tutorials can now be used again and again, you know, maybe modifying them a bit, but yeah, from one year to the next you can always use these tutorials again.

R3_17 RESEARCHER: And you mentioned that it might be somewhat dependent on how you would use flipped content, are there factors that you would consider, so things like different types of students, or topic taught, classroom setup or year level, that you would feel are better to flip than others?

T3_17 TEACHER PARTICIPANT: Umm.. possibly in Year 9 and Year 10, at this stage. With any Algebra topics, and topics such Trigonometry and ummm… measurement, mainly. Where there is that need for repetition of skill. However, in Year 7 and 8, it would probably be more, I suppose, appropriate to have that classroom sort of, explanation and discussion.

R3_18 RESEARCHER: And what’s your gut-feel on that, why do you think Year 7 and 8 might benefit for from that?

T3_18 TEACHER PARTICIPANT: Ummm… with the students having just come from a primary school, the fact that they have been discussing in the classroom and asking questions and having the opportunity to listen to others. I think it would be more beneficial for them. And maybe there is more opportunity for that in the types of topics we do at those levels…ummm, yes…but in year 9 and 10, I think there is more responsibility as well from the students, they know if work is not done, they know there is going to be consequences if they are not keeping up with the work. But at Year 7 and 8, I think… I don’t know, maybe we just need to try it!

R3_19 RESEARCHER: And so then, I guess on balance, how do you see your curriculum next year? Is it going to be impacted by the flipped classroom, and if so how will that play out?

T3_19 TEACHER PARTICIPANT: It will be, yes. Um, so, I’m looking at having other units prepared using tutorials and using flipped learning. So yeah, it was a good impact, especially when you’ve got the same class, you know you’ve got two or three of the same classes as well. It is quite efficient to have the tutorials and then they come to your classroom prepared, and then you have the opportunity to just go around and help individual students…because to repeat the same things twice or three times a day… it can be draining.

R3_20 RESEARCHER: And.. again, because you're in the best position to comment on this, having it so fresh, what advice would you offer to somebody wanting to start out in creating flipped lessons in maths?

T3_20 TEACHER PARTICIPANT: It's a good experience, it's good to try, possibly it might not work out for everybody and every class, it is a challenge and it's time consuming but I think the end result is worth it.

R3_21 RESEARCHER: And what sort of training and resources do you think teachers would need in order to be successful with flipping some lessons?

T3_21 TEACHER PARTICIPANT: As long as someone is comfortable to record themselves and use the appropriate tools.. umm, the tools you need; they need to be able to sort of manage all of them and make your notes clear for the students, or else you spend a lot of time preparing notes and the students still won't get it. Ummm..but if you've got the right tools and you're comfortable recording, there shouldn't be any problems… anybody should be able to do it. If I've done it, I think everybody can do it.

R3_22 RESEARCHER: Can you please elaborate on what you mean by tools? I.e. maybe list and/or describe these tools?

T3_22 TEACHER PARTICIPANT: The most important tool is the notes I prepared, that they clearly showed and explained the skill step by step. Then the way I did my flipped videos was using the Microsoft OneNote program on my MacBook to type in the notes and questions for each tutorial. The Intuous tablet was connected to the laptop and I have used it to write on the OneNote whilst explaining the notes and examples and recording it all using Quicktime player. I found using headphones wasn't necessary as long as I was in a quiet place.
After the tutorials have been recorded, I have uploaded them on EdPuzzle and added some quiz questions to each tutorial. Once tutorials are finalized I started sharing them with my students, one or two at a time.

R3_23 RESEARCHER: OK, and so if I was to start out tomorrow, and I said TEACHER NAME, I want to flip my maths lesson, what would be the first thing you would say I would need to do in order to be successful with that?

T3_23 TEACHER PARTICIPANT: Ok, well first of all you should write the notes that you plan on giving to the students. Once you've got that unit written into separate notes, separate lessons, umm.. well what I used then was EdPuzzle and the Intuous and QuickTime player. Those three together, umm you know, you can then setup your tutorials.

R3_24 RESEARCHER: And anything that you would feel inclined to warn me about, about the whole process or..?

T3_24 TEACHER PARTICIPANT: Try not to be that perfect and it's OK to make mistakes in the videos and…ummmm… just when you're explaining things, just pretend you're in the classroom explaining them, and that's how you will explain them in your tutorials.

R3_25 RESEARCHER: OK, and that's, the teacher side of things. However, given you've gone through this with a student group, what advice do you think is pivotal for students to have in order for them to be successful with this new type of learning?

T3_25 TEACHER PARTICIPANT: As long as they keep up with the teachers instructions with when they should watch the tutorials and what to do with those tutorials, then work hard in class and use the teachers assistance, I think that's the most beneficial, when they will benefit the most out of the flipped learning.

R3_26 RESEARCHER: Ah last interview, at the half-way point, we were discussing the fact that you were finding more time in your flipped lessons for students to work on things, did that continue?

T3_26 TEACHER PARTICIPANT: During the flipped, yes, it was continuous. Yes and it was good because you would start noticing that students have the same difficulties, so when one, two, three students are asking me about the same question…usually when we get to the problem solving and reasoning questions, I ask for everyone's attention and we work it out together on the board.

R3_27 RESEARCHER: And, also in that half-way interview you were discussing that you felt that the flipped group was doing better than the non-flipped group, or seemed to be performing a little bit better, did that show up in the results at all, in the post test?

T3_27 TEACHER PARTICIPANT: Ah not clearly, no. So, there were what looked to be similar improvements in both groups. Ummm…so unless sort of analysed more deeply, both groups have increased their level of Algebra skills.

R3_28 RESEARCHER: And, ahhh, again going back to that mid-way interview, you discussed the notion of having a lower stress level in walking into the flipped classes. How did that carry on towards the end of the unit, did you find that stayed the same?

T3_28 TEACHER PARTICIPANT: Same thing, yes, same thing. Yes, because again by the end students knew what they had to do etcetera and so it was a matter of a repetitive sort of procedure… OK, lets discuss some difficulties….and even the students sort of looked more relaxed they knew what was going to happen and they were ready to get on with their work.

R3_29 RESEARCHER: And how did you find that the students took to it as time went on? So, at the halfway interview we discussed that there were some issues at the start with students clicking in, you know, during another lesson, and you'd spoken about the expectations about that. Did their patterns or behaviours, or, I guess, completion rates change in any way, or once they got it they got it?

T3_29 TEACHER PARTICIPANT: Once they got it, they got it. So, the few of them that were, you know, watching it in the same morning, that stopped. That stopped completely. They realised that others are watching it before hand and those others were moving ahead, so they quickly went onboard with that.

R3_30 RESEARCHER: And just out of curiosity, did you notice, ahhh, any difference in the contributions of certain types of students. So perhaps a student who was known for being quiet in previous units started to speak more or vice-versa, or was it the same dynamic in the class?

T3_30 TEACHER PARTICIPANT: I think it was the same dynamic….yes. If they were quiet, they were still quiet. However, they were working more.

R3_31 RESEARCHER: And, we also mentioned in the last interview if you had the opportunity to use the flipped content in other lessons, and at that stage you hadn't, has that changed at all?

T3_31 TEACHER PARTICIPANT: No, the flipped content has only been used so far by the flipped class.

R3_32 RESEARCHER: Yep, well in terms of questions that covers it from my end. Is there anything that we haven't drawn out in the whole process or anything that you would like to comment on that might be worthwhile for us to hear?

T3_32 TEACHER PARTICIPANT: Ummm, no, I think that's it.

R3_33 RESEARCHER: Still happy for you to add anything to this.

T3_33 TEACHER PARTICIPANT: Students in the flipped group had the opportunity to and did ask more Reasoning and Problem solving related questions that they had difficulty completing in class. These difficulties were discussed with the whole class when I realise that a few students were enquiring about a particular question.

As for the non-flipped group, students rarely admitted to having problems with Reasoning and Problem Solving questions whilst doing their work at home.

However, I didn't think that the advantage/s of this could not be shown in the SMART test results as it did not consist of Reasoning and Problem Solving questions.

Appendix P. Student Comments (Verbatim) to Post-Topic Survey

Cluster	Student Comment
Video explanations allow students to control the pace of their learning	▪ With the videos you can pause and re watch different sections and go at your own pace [S8-1] ▪ ….It was easy to work/write at my pace [S7-1] ▪ I like doing maths through the videos because I can go at my own pace and pause the video whenever I need it and it gives me more time to understand the concepts. [S4-1] ▪ … Watching on the video was better for me than getting the notes in class because I was able to take my time writing it [S22-1] ▪ …I was able to work at a pace which was comfortable for me, and allowed me to work on some problems for however long I needed in order to get the correct answer… [S17-1] ▪ … On the videos I am able to learn at my own speed [S3-1] ▪ Learning Mathematics through video is easier because you can learn it at your own pace… [S14-1] ▪ … I can take as much time as I want to write things down but in class I have to write things quickly or I have to wait till the teacher finishes writing down things before I can copy it. [S16-1] ▪ … The videos were good that you were able to go at your own paste and replay… [S2-1] ▪ I prefer learning using a video because it allows me to work in my own pace… [S20-1] ▪ I liked the online learning because when I write questions for my notebook in class I'm usually disengaged and I can't take breaks when I feel like I need to take them, also, when I'm writing the questions down I barely have enough time to process the whole thing and then evaluate my questions which in my humblest opinion, think it wastes a lot of my time. [S13-1] ▪ I like doing maths through the videos because I can go at my own pace and pause the video whenever I need it and it gives me more time to understand the concepts. [S12-1] ▪ i didn't have to pay as much attention while doing flipped classroom because i could always pause and re-watch if i needed to. [S19-1]
Students re-watch video explanations as needed	▪ … I could go back and re-watch the video anytime if I needed to. [S22-2] ▪ … if you need to go back and watch it again you have that option. [S14-2]

	▪ its better to watch my teacher explain concepts through a video because i can watch videos over and over until i get it [S23-1] ▪ I can also watch the video again to get a better understanding of the concepts. [S20-2] ▪ I liked the aspect of being able to watch the video again … [S2-2] ▪ The videos I believe is better for me as I can re-watch a video as many times I need to understand the subject [S3-2]
Students want to are able to learn independent of the needs of others	▪ I preferred when the videos were used because I didn't have to sit there and listen to everyone in the classes individual issues, I got to just get my work done... [S9-1] ▪ People have the opportunity to copy down notes and people don't have to wait for others. [S20-3] ▪ … I don't have to wait for others or others don't need to wait for me … [S3-3]
Embedded formative assessment in video explanations assists student learning	▪ … I liked how we had questions that we could test ourselves and if we got them wrong it'd be explained the next day. [S13-2] ▪ … in class, the teacher was able to point out and explain whatever difficulties students found in some example questions. [S17-2] ▪ The quizes made you to make sure that you were paying attention and not just taking notes [S2-3]
Inability to get immediate clarification from the teacher when difficulties in video explanations are encountered is problematic for students	▪ but I am able to ask questions on the spot if something is not clear. [S3-4] ▪ In the video I can't ask things when I don't really understand something and in class I can. [S16-2] ▪ if there was a misunderstanding, you would have to wait until next class which impacted on the amount of time allowed for the exercise. [S2-4] ▪ I think having it explained in class is much better because i can ask questions and receive information i wouldn't be able to in video form [S11-1] ▪ … I think the faults with the flipped classroom method are that if I was not understanding what the teacher was explaining than I could not raise my hand a ask a question. [S1-1] ▪ …in class we can go over it but obviously in the tutorials we can't ask the teacher about our struggles. [S21-1]
Ability to seek clarification from the teacher in class after difficulties in video explanations are encountered is utilised by students	▪ even if I do have some difficulties understanding something, I can always ask the teacher during our lessons. [S17-3] ▪ …and if you had difficulty you can just tell the teacher at school [S18-1] ▪ … in class the teacher can help me figure out any difficulties that im having [S9-2]

In class examples enable more in-depth explanation of content	▪ …but I like class also as we go into more depth and if someone isn't sure… [S21-2] ▪ I prefer when she explains it in class because it's easier to follow and ask questions if I get confused. [S6-1] ▪ I prefer the normal math classes as if needed more examples and more of an explanation can be given [S2-5]
Watching video explanations at home enabled more time in class for teacher assistance	▪ I prefer learning from the videos on our laptops at home because then I get more time in class to do the exercise and ask questions to the teacher about any struggles I have. [S12-2] ▪ … so if you had another difficulty it would be easier to ask the teacher for help. [S18-2] ▪ The video because I like to do the notes on my own and when it comes to the exercises have the teacher there for assistance if needed. [S22-3] ▪ I personally prefer watching videos at home because when it is time to work i can have help and ask questions and develop strategies to help me answer questions where as at home i wouldn't be able to do that [S11-2]
Reviewing video explanations improved understanding	▪ so that if i needed clarification for something, I just went back and rewatched until it made sense [S9-3] ▪ … if I didn't understand a question I could keep replaying. [S21-3] ▪ I decided to this so that i could receive a proper understanding of the concept being taught to me [S11-3] ▪ i did rewind my videos because i wanted to make sure im doing it properly … [S23-2] ▪ … I rewinded the videos when I was unsure of what was explained in the video. [S1-2] ▪ Being able to acquire a better understanding of what I am trying to learn by rewinding. [S14-3]
Ability to pause a video enables time to process new skills or concepts	▪ … especially during the exercises so it gave me more time to process the information given to me [S12-3] ▪ Sometimes I was confused as to what I was writing and pausing allowed me to stop and think [S7-2] ▪ So that I fully understood how to do the equation step by step. [S22-4] ▪ I often paused because I couldn't keep up with the video which was annoying [S6-2] ▪ … i also paused so i can get a good view on how to do it [S23-3] ▪ i paused the videos due to the video going really quickly… [S15] ▪ The difference was that you had time to process, write and evaluate everything you've done in the

	video, in comparison to when you're in maths class and you're being fed the answers. [S13-3]
Ability to pause a video allows time to copy examples/notes	▪ i needed to pause the videos so i could write down all the notes, i didn't really miss any information. [S19-2] ▪ I decided to pause videos so I can copy down notes. [S20-4] ▪ I usually paused the video at the start and copied down the notes on the screen and once I had done this, I played the video and listened to what the teacher was explaining/talking about. Then pause again and copy the next notes and play it again. [S17-4] ▪ I paused the videos when I had to write down notes…[S1-3] ▪ I paused the videos so that I could copy the things already on the video before I play it or I wait till the teacher is done writing things down and I pause it and copy everything into my book [S16-3] ▪ I paused to be able to write down all the notes and examples… [S2-6] ▪ I decided to pause and re wind so that I would be able to copy the notes better … [S18-3] ▪ I decided to go back so I could get the note properly. [S10-1] ▪ …it gave me time to write notes and pace myself… [S13-4]
Preference for teacher's voice in flipped video explanations	▪ If these videos were sourced from the Internet is would make a difference as the videos from the Internet could be teaching differently. [S20-5] ▪ Yes, as I know my teachers methods better [S7-3] ▪ Yes. They wouldn't help me as much because the content would be a bit different and also the teaching style. [S21-4] ▪ … in some way it would have made a difference as I probably would not know who is speaking and if the information they are providing me with is reliable, or if they even knew what they were doing/explaining. I also would not know whether or not they are a qualified maths teacher. [S17-5] ▪ … because everyone might have different ways of solving a problem which could be quite confusing. [S16-4] ▪ Possibly as it might not have been as easy to understand as it could be a different style/method to which we are use to [S2-7] ▪ … the teachers might've not watched the video and therefore not understand the limits of our learning. [S13-4]

	▪ … It does because the videos my teacher creates specify on the exact thing we are learning. [S14-4] ▪ … the internet the video might not make sense to me because the video wouldn't have all the detail that the students need and also the teacher knows how the students need to learn so it will make it easier for the students to learn unlike a generic video from the internet. [S18-4]
No preference for teacher's voice in flipped video explanations	▪ … as long as the same information I needed was in the video. [S22-5] ▪ No difference as long as it's the same content [S3-5] ▪ no because it would be explaining the same thing [S23-4]
Watching video explanations alone assisted concentration	▪ I did it on my own because it was easiest for me to concentrate. [S22-6] ▪ I watched it on my own so I could concentrate. [S20-6] ▪ I did it by myself so i could focus on it [S9-4] ▪ I did it on my own so that i can focus and keep on track [S11-4] ▪ I watched the video on my own because i would focus on the video better but if I had a person there i wouldn't have focused as much so I decided to watch the video on my own... [S18-5] ▪ I watched the video on my own so that I was able to concentrate and focus [S2-8] ▪ I watched the videos by myself because I learn better without distractions around me. [S1-4] ▪ it was one on one so it was kinda more easier to concentrate [S23-5]
Students opt to watch video explanations alone to suit their needs	▪ I just like/prefer to work on this type of work alone. [S17-6] ▪ I completed it on my own because I find it harder to work with someone other than my teacher. [S14-5] ▪ I did it on my own because I didn't really need to do it with anyone and there was no real reason to watch it with someone. [S16-5] ▪ On my own. I treated it like I was in the classroom and didn't have a need to watch it with anyone. [S21-5] ▪ I did it on my own because I felt more comfortable with it [S6-3] ▪ on my own because i completed it at my house and like doing home work alone [S4-2]
Flipped classroom supports ease in student learning	▪ i would like to see more flipped learning because of the ay that the video helped me learn and it was easy to understand. [S15] ▪ flipped because it is easier [S14-6]

	▪ I would like to see the flipped classroom more in the future because writing notes down was a problem to me in class and being able to do it at home is much easier for me. [S16-6] ▪ I would like to do flipped learning again because it did make it easier for me to learn. [S18-6] ▪ … It seems easier [S10-2] ▪ It's easy to follow … [S20-7] ▪ … I feel like it takes stress off us and more oppertunities to solve difficulties. [S12-4]
Flipped learning is an effective way to learn mathematics	▪ I'd like to see more of the online learning; it's creative, useful, time efficient and it takes full advantage of modern day technology. [S13-5] ▪ the flipped classroom is better as it teaches the same content and in shorter periods and at your own speed [S3-6] ▪ Flipped learning because i believe it is a more effective way of teaching [S11-5] ▪ I would like to see more of flipped learning as I enjoyed this type of learning better. [S17-7]
Regular classroom (non-flipped) supports student learning	▪ maybe keep it normal because if I get tuck the teacher can help me in class and push me to work harder [S8-2] ▪ I would prefer notes in classroom because it will be easier for people to keep up with [S6-4]
Easy to lose focus when watching video explanations at home	▪ Id prefer the standard method only because i get distracted more at home [S4-3] ▪ I probably prefer learning in a classroom, as it is easier to lose focus when at home. I think it takes longer for me to watch the videos and take the notes at home, therefore taking more time out of my personal life. Usually it does not take me so long to do math homework because the exercises usually set do not take as long to do. [S1-5]