Student learning experiences with the online component of a partially flipped teaching model

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Statement of Authenticity

The work presented in this thesis is, to the best of my knowledge and belief, original, except as acknowledged in the text. I hereby declare that I have not submitted this material, either in whole or in part, for a degree at this or any other institution.

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List of Abbreviations

ANOVA	Analysis of Variance
AL	Approach to learning
BP	Behavioural pattern
CHEM1001	Fundamentals of Chemistry 1A
CHEM1002	Fundamentals of Chemistry 1B
CHEM1101	Chemistry 1A
CHEM1102	Chemistry 1B
CHEM1901	Chemistry 1A advanced
CHEM2401	Molecular Reactivity and Spectroscopy
CHEM2402	Chemical Structure and Stability
CHEM2403	Chemistry of Biological Molecules
CHEM2404	Forensic and Environmental Chemistry
CHEM2911	Molecular Reactivity and Spectroscopy (Advanced)
CHEM2912	Chemical Structure and Stability (Advanced)
CHEM2915	Molecular Reactivity and Spectroscopy (Special Studies Program)
CHEM2916	Chemical Structure and Stability (Special Studies Program)
CR	Credit
DA	Deep Approach
DI	Distinction
FA	Fail
GPA	Grade Point Average
HREC	Human Research Ethic committee
HD	High Distinction
HE	High Engagement

HSC	Higher School Certificate
HSD	Honesty Significance Difference
LE	Low Engagement
ME	Moderate Engagement
HE	High Engagement
NSW	New South Wales
NHMRC	National Health and Medical Research Council
PIS	Participant Information Sheet
POGIL	Process Oriented Guided Inquiry Learning
P	Pass
SA	Surface Approach
SSP	Special Studies Program
STEM	Science, Technology, Engineering and Mathematics
WAM	Weighted Average Mark

Abstract

Flipped learning has received increased recognition as an innovative pedagogical approach that has the potential to improve students' learning experience in higher education. This approach creates a 'reversed' learning experience, where portions of the didactic lecture traditionally presented in class is moved online in the form of pre-learning materials. There is increasing evidence that this leads to improvements in academic performance with the online pre-learning materials being an underlying factor.

This thesis reports student behavioural engagement, behavioural patterns, and approaches to learning with the online component of a partially flipped learning model and its impact on student academic performance in chemistry courses. An engagement index was developed to quantify student engagement levels with pre-learning materials. The findings revealed higher levels of engagement led to significant improvements in academic performance. Several patterns were detected when measuring students' frequency of access for each of the pre-learning materials. The dominant pattern revealed that students tend to favour accessing a pre-learning quiz more frequently than the video. Most students self-identified to be strategic learners and were categorised to be moderately or highly engaged with a preference to accessing the quizzes more frequently than the videos. Students reported that weighting of the quizzes, although low, was a motivating factor for completion. The most pronounced differences in academic performance were observed in the mainstream rather than advanced courses, suggesting that the online component mainly benefited students with lower proficiency levels of chemistry. Recommendations regarding the design of the pre-learning materials were proposed to enhance student engagement, encourage the desired behavioural pattern and adoption of a deep learning approach.

Chapter 1: Introduction

1.1 Brief background

Flipped learning has gradually emerged, receiving increased recognition as an innovative pedagogical approach that has the potential to improve students' learning experience in higher education (Birgili, Seggie, & Oğuz; 2021; Bredow, Roehling, Knorp, & Sweet, 2021; O'Flaherty & Philips, 2015). Flipped learning "at its simplest, involves pushing lecture material outside the classroom as a form of homework or other pre-class preparation, leaving more time in class for interactive or engaging exercises" (Smith 2013, p. 607). Thus, flipping the instructional design of a course creates a reversed learning experience when compared to traditional teaching paradigms (Bergmann & Sams, 2012; Hamdan, McKnight, McKnight, & Arfstrom, 2013). The degree and the extent in which a course is "fully" or "partially" flipped varies widely across different educational contexts and depends on the intended learning outcomes (Burgoyne & Eaton, 2018; Flynn, 2015; Roach, 2014; Seery, 2015). To effectively implement this pedagogical approach, some portions of the didactic lecture traditionally delivered in class are moved to an online pre-learning environment (Bishop & Verleger, 2013; Lage, Platt, & Treglia, 2000). This allows students to gain initial exposure to foundational knowledge required for the in-class session where they engage in a series of active learning opportunities (Bergmann & Sams, 2012; Hamdan et al., 2013).

Many studies have relied primarily on students' self-reported data in the form of questionnaires or think-aloud methods (Jovanović, Gašević, Dawson, Pardo, & Mirriahi, 2017) to examine the relationship between students' behavioural engagement and academic performance. The data gathered from these self-reported measures may often be subjective to recollection biases as they are not captured in real-time (Dazo, Stepanek, Fulkerson, & Dorn, 2016). While most studies have focused on students' behavioural engagement with the in-class component of the flipped learning model (Cormier & Voisard, 2018; Smallhorn, 2017), limited research has explored their behavioural engagement with the pre-learning materials. However, the pre-learning materials are perceived to be a critical feature in providing students with the foundational knowledge needed for the in-class session where they actively engage in building their procedural and conceptual understanding of course content (Cormier & Voisard, 2018; Ryan & Reid, 2016). In addition, there is increasing evidence suggesting that students' online behavioural engagement with the pre-learning materials may also be a contributing factor that impacts their academic performance (Wang; 2017; Wang, 2019). Recent studies have suggested the use of learning analytics as an alternative approach to self-reported data to quantify students' online behavioural engagement with the pre-learning material (Jovanović et al., 2017; Wang, 2019). The data gathered from these measures provide direct evidence of students' actual behaviour which can supplement the current understanding of how varying levels of engagement with the online pre-learning material can impact students' academic achievement.

Further research exploring students' online behavioural engagement often focused on identifying context specific trends with the individual components of the pre-learning materials and its impact on academic performance (Beatty, Merchant, & Albert, 2019; Dazo et al., 2016; Long, Wang, Yang, & Chen, 2019). Other studies have expanded on this by providing a more profound understanding of students' overall behavioural patterns with several pre-learning materials (Brennan, Sharma, & Munguia, 2019; Jovanović et al., 2017). Despite this, there is still limited empirical evidence focused on examining the diverse distribution of online behavioural patterns with the pre-learning materials and its potential correlation with academic performance (Brennan et al., 2019; Jovanović et al., 2017). It has been proposed that the learning process and strategies students adopt may influence their behavioural pattern and behavioural engagement (Jovanović et al., 2017). Several studies have suggested that a flipped learning environment has the potential to influence students' approaches to learning and promote deep engagement with the learning materials (Jeong, González-Gómez, Cañada-Cañada, Gallego-Picó, & Bravo, 2019; McLean, Attardi, Faden, & Goldszmidt, 2016). However, little focus has been placed on the approach students adopt whilst completing the pre-learning materials. It is expected that the knowledge they have gained from the online component can facilitate deep learning to occur during the in-class session (Eichler, 2022; McLean et al., 2016). The relationship between students' behavioural engagement, displayed behavioural pattern, adopted approach to learning and their impact on academic performance remains largely underexplored.

1.1.1 Research aims

The focus of this thesis is to evaluate an existing partially flipped learning model, implemented in the chemistry courses at the University of Sydney as part of a curriculum renewal to improve students' learning experience. In this thesis three distinct yet interrelated research studies will be presented. The studies focus on examining (1) second year students' online behavioural engagement, (2) behavioural patterns, and (3) approaches to learning with the online component of a partially flipped learning model and its impact on their academic performance in intermediate chemistry courses. While this thesis predominantly focuses on intermediate chemistry courses, parallel data from junior chemistry courses were gathered to compare students' approaches to learning.

The aim for the **first study** was to:

- Develop a behavioural engagement index as part of this doctoral research project.
- Measure students' behavioural engagement with the online component using the specifically developed engagement index (as part of this doctoral research project) and the impact of their behavioural engagement on their academic performance.
- Identify potential factors that may have influenced students' behavioural engagement.

An engagement index was developed to quantify students' behavioural engagement levels with the pre-learning materials in the online component of partially flipped learning model. The following questions were addressed:

1. What is the effect of students' behavioural engagement with the online component on their academic performance?
2. What are the factors that affect students' behavioural engagement with the online component?
3. How do changes in students' behavioural engagement across consecutive semesters affects their academic performance?

The aim for the **second study** was to:

- Identify students' behavioural patterns with the online component and its impact on their academic performance.
- Evaluate students' perceptions towards the pre-learning materials.

Behavioural patterns were established based on the frequency of access for each of the two pre-learning materials: pre-learning videos and pre-learning quizzes. The following questions were addressed:

1. How do students interact with the pre-learning videos?

    a. How does student viewing behaviour correlate with academic performance in the weekly online pre-learning quizzes, overall online pre-learning quiz score and the online in-semester quizzes?
2. How do students interact with the online pre-learning quizzes?
    a. How does student interaction with the pre-learning online quizzes correlate with the online in-semester quizzes?
3. What behavioural patterns can be identified using aggregated data from students' interaction with the online pre-learning material?
    a. How does student behaviour with the pre-learning material change over the course of a semester?
    b. How does student identified learning behaviour relate to their academic performance?
    c. How does student identified learning behaviour relate to their behavioural engagement level and their academic performance?
    d. What is the association between the students' identified learning behaviour and their engagement index group?
4. What are students' perceptions towards the pre-learning material of a partially flipped learning environment?

The aim for the **third study** was to:

- Explore students' self-identified approach to learning and its impact on their academic performance.
- Compare students' self-identified approach to learning with their observed and self-described approach.

Students' self-identified approach to learning was measured using Biggs et al. (2001) Revised Study Process Questionnaire (R-SPQ-2F). The following questions were addressed:

1. How do students approach learning in the online component of the flipped learning model and how does it affect their academic performance?
2. How does a student's self-identified approach to learning relate to their behavioural engagement level and their behavioural pattern in the online component?

1.2 Significance

This thesis contributes in several ways to current research on partially flipped learning models in undergraduate chemistry courses by focusing on the online component.

Firstly, the engagement index developed uses learning analytics as an alternative approach to quantify students' online behavioural engagement which expands on existing frameworks and traditional research methods of developing engagement models that often rely on students' self-reported responses. It provides an insight on *how* students engaged with the pre-learning materials, change their online behaviours between consecutive semesters and how their online behavioural engagement relates to their academic performance. Furthermore, it can be used to detect online [dis]engagement and provide teachers with insightful data allowing targeted support and personalised feedback.

Secondly, the identified behavioural patterns based on the frequency of access for each of the two pre-learning materials provide valuable insight regarding the dominant displayed behavioural pattern(s) and how these may change over the course of a semester.

Thirdly, the self-identified approach to learning gathered from the R-SPQ-2F questionnaire can identify the learning process and strategies students adopt while accessing the pre-learning materials. In addition, it provides a comprehensive understanding on how students' self-identified approach to learning aligns with their observed and self-described approach and what factors prompted them to adopt a particular approach.

Finally, the combined data gathered from students' behavioural engagement, behavioural pattern and self-identified approach to learning can inform future designs of the partially flipped learning model. More specifically: (1) how to design pre-learning materials that can encourage higher levels of engagement, (2) display behavioural patterns that access both pre-learning materials, and (3) ways to adjust the nature of the pre-learning materials to encourage students to adopt a deep approach towards learning.

1.3 Structure of the thesis chapters

This thesis focuses on examining the impact the online component of a partially flipped learning model had on students' behavioural engagement, behavioural pattern, approaches to learning and its effects on students' academic performance and perception in undergraduate chemistry courses. The three research studies were conducted with one cohort of first year undergraduate students in junior chemistry courses and two cohorts of second year undergraduate students in intermediate chemistry courses.

This introductory chapter provides a brief background of the rationale for flipped learning, followed by the research questions investigated and their significance to the research field. The first part of Chapter 2 outlines general learning theories and frameworks related to educational research. The second part of Chapter 2 provides a critical review of the existing research on flipped learning, identifies emerging trends related to the online component which informed the research reported on in this thesis. Chapter 3 outlines the methodology used by focusing on the philosophical underpinnings behind the quantitative and qualitative research methods used to gather and analyse the data. The second part of Chapter 3 describes the context of the study and presents a detailed overview of the partially flipped learning model implemented in the chemistry courses, with information about each of the investigated chemistry courses. Chapter 4 proposes an engagement index to quantify students' behavioural engagement with the online component of a partially flipped learning model and its impact on their academic performance. In addition, it proposes factors that may have influenced students' online behavioural engagement. Chapter 5 details an investigation of patterns in students' behavioural engagement with the online component of a partially flipped learning model. In addition, it explores changes in weekly interaction with the online pre-learning material and its effect on academic performance. Also discussed in Chapter 5 is students' perception towards the online component of a partially flipped learning model. Chapter 6 explores students' self-identified approach to learning and its impact on their academic performance. The use of observational and follow up interviews provide valuable insight regarding students' self-identified approach to learning and factors that may have contributed to their adopted learning processes and strategies. Further analysis was carried out to compare students' self-identified approach to learning with their online behavioural engagement and behavioural pattern discussed in the previous chapter. Finally, Chapter 7 briefly summarises the key findings, discusses the implications of the research findings and highlights key limitations and recommendations for future work with some concluding remarks on the research reported on in this thesis.

Chapter 2: Literature review

2.1 Brief overview

There is an increasing demand to implement innovative pedagogies in higher education that extend students' learning experience "beyond developing subject specific knowledge and understanding" (Armellini, Antunes, & Howe, 2021, p. 434). These can equip students with the necessary skillsets to address the learning needs of the twenty first century which include core competencies such as critical and analytical thinking, problem solving and collaboration (Trilling & Fadel, 2009; Zhao, He, & Su, 2021). In response, flipped learning has recently emerged as a pedagogical approach that creates a reversed learning experience when compared to traditional teaching paradigms. The theoretical framework of a flipped learning model is grounded in constructivism. The online and in-class components of this pedagogical approach are designed to involve students in the learning process by actively constructing their own knowledge. The research reported on in this thesis focuses on examining students' learning experience by exploring their behavioural engagement, behavioural patterns, and self-identified approach to learning in the online component of a partially flipped learning model implemented in undergraduate chemistry courses. The first part of this chapter outlines general learning theories and frameworks related to educational research. The second part provides a critical review of the existing research on flipped learning, identifying emerging trends related to the online component which informed the research reported on in this thesis.

2.2 The philosophical foundations of research

It is essential to consider the philosophical foundations of research, as they inform the direction(s) of a research study. Grix (2004) outlines the interrelationship between five essential building blocks of research (see Figure 2.1). Furthermore, Grix (2004) proposes that:

> "By setting out clearly the interrelationship between what a researcher thinks can be researched (her ontological position), linking it to what we can know about it (her epistemological position), and how to go about acquiring it (her methodological approach), you can begin to comprehend the impact your ontological position can have on what and how you decide to study" (p. 68).

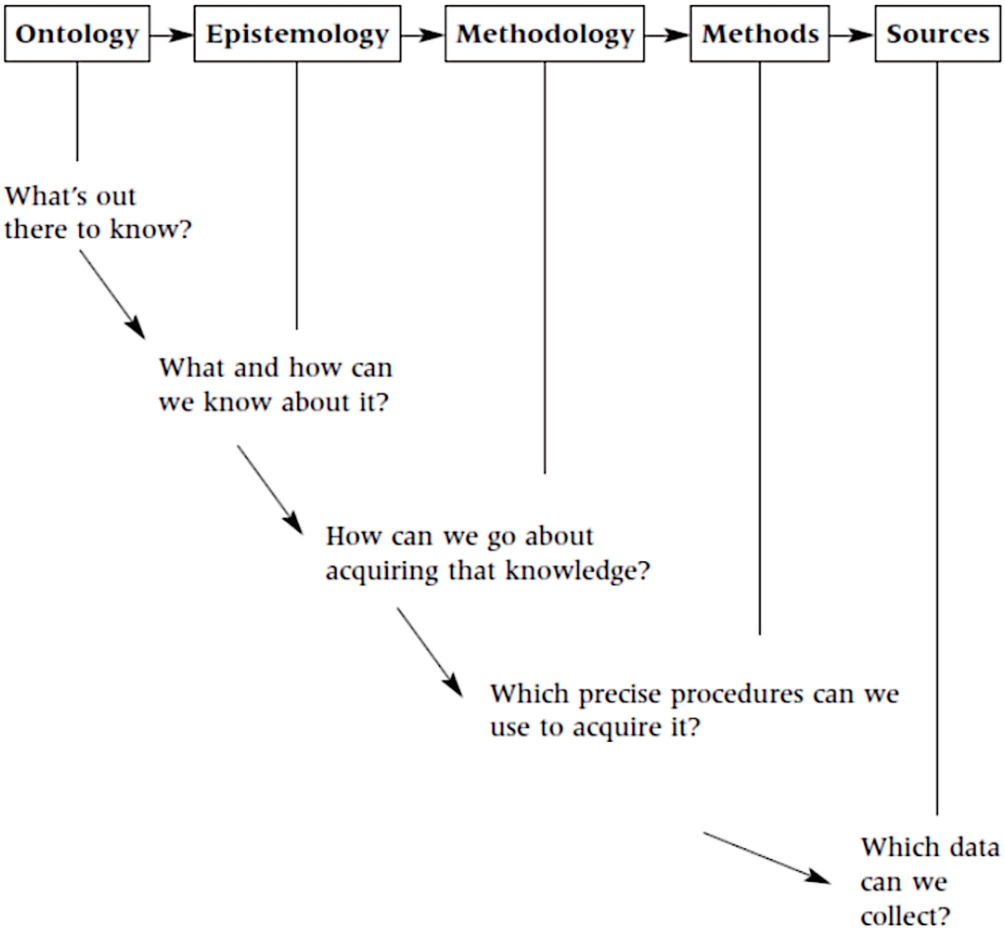

Figure 2.1. The interrelationship between the building blocks of research (extracted from Grix, 2002, p. 180).

Krauss (2005) further expands on three of these interrelationships by suggesting that "epistemology is intimately related to ontology and methodology; as ontology involves the philosophy of reality, epistemology addresses how we come to know that relatively while methodology identifies particular practises used to attain knowledge of it" (p. 759).

Allison and Pomeroy (2000) explored the principles of ontology and epistemology and identified distinguishing features of both. Ontology refers to the "nature of reality" and proposes two views with some suggesting that "reality is out there to be discovered whereas others consider that reality is socially constructed" (Allison & Pomeroy, 2000, p. 92). As such, ontology focuses on exploring *what* is real. Epistemology refers to "the nature of knowledge" and thus focuses on "questioning the sources of knowledge, the assumptions upon which it is based" (Allison, 2000 as cited in Allison & Pomeroy, 2000, p. 92) and therefore questioning the relationship between what is known and what can be known. Others propose that epistemology can also refer to the "extent of human knowledge" (Williams, 1996). As such, epistemology focuses on exploring *what* constitutes knowledge, *how* can knowledge be attained or produced and *how* to evaluate the degree of its transferability. The underlying principles of ontology and epistemology can influence the philosophical lens and which learning theory will be used to explore research.

2.3 The philosophy of learning

2.3.1 Early theory of learning

While the theoretical framework underpinning the educational research reported on in this thesis is constructivism, it is essential to review how it developed from early theories of learning. Early theories have been recognised as adopting a teacher-centred approach towards learning where "the accepted model for instruction was based on the hidden assumption that knowledge can be transferred intact from the mind of the teacher to the mind of the learner" (Bodner, 1986, p. 873). This view suggests that knowledge is merely transmitted, and as such, the learner passively acquires the knowledge being presented by the teacher.

Rationalism is an early epistemological view that perceives knowledge to be innate, or inborn, and that it can be acquired through intellectual and deductive reasoning rather than from sensory experiences (Thomas, 2009). Neimeyer and Morton (1997) expand on this further and suggest that rationalism:

> "(a) argues for the distinction between thinking and feeling, (b) favours thinking as a superior vehicle for validating knowledge, and (c) adheres to a realist version of ontology, in which there is a single, stable, and potentially knowable external reality" (p. 110).

Another early epistemological view is *empiricism* which suggest that knowledge, mainly if not exclusively, is acquired from sensory experiences (Childers, Hvorecký, & Majer, 2021). *Behaviourism* is a perspective that evolved from this and "is restricted to externally observable inputs (known as stimuli) and outputs (known as behaviour)" (Childers et al., 2021, p. 2). This view discards the idea that "mental entities are explanatory" but instead explains behaviours to be fundamentally related to observable events.

2.3.2 Constructivism and social constructivism

Early work conducted by Dewey (1916) informed Piaget cognitive constructivism theory (1952) which propose that "learners form or construct their own understanding of knowledge and skills" (Schunk, 1996, p. 230).

Bodner (1986) expands on this suggesting that:

> "Knowledge is constructed in the mind of the learner… they do not simply mirror and reflect what they are told or what they read. Learners look for meaning and will try to find regularity and order in the events of the world even in the absence of full or complete information (pp. 874-876).

Piaget's cognitive theory was derived from ideas on children's cognitive development. This depends on four factors: "biological maturation, experience with the physical environment, experience with the social environment, and equilibration" (Schunk, 1996, p. 236). The process of equilibration has received significant recognition with two main components identified: assimilation and accommodation which focus on how learning can occur in the mind of the learner instead of what influences them to learn. Assimilation is defined as the process "of fitting external reality to the existing cognitive structure" (Schunk, 1996, p. 236) whereas accommodation "refers to changing internal structures to provide consistency with external reality" (Schunk, 1996, p. 236). Schunk (1996) proposes that assimilation and accommodation "are complementary processes as reality is assimilated, structures are accommodated" (p. 236).

Vygotsky's (1978) social constructivism theory of learning was not focused "on the internal structure of concepts and the individual student but instead the social context" (Cooper & Stowe, 2018, p. 6057) or cultural context within which learning can take place. Vygotsky suggests that an individual student may achieve a higher level of learning with the assistance of a more knowledgeable teacher or peer. This form of scaffolding is formally referred to as the zone of proximal development which is defined as:

> "The distance between the actual developmental level (of a student) as determined by independent learning and the level pf potential development as determine through learning under the guidance of a teacher, or in collaboration with more capable peers" (Vygotsky, 1978 as cited in Copper & Stowe, 2018, p. 6057).

Both these theories reinforce the notion that "knowledge is constructed in the mind of the learner, and they emphasize that, for useful and transferrable learning to occur, connections must be constructed between what is known and what is to be learned" (Copper & Stowe, 2018, p. 6057). Ausubel further refines the notion of constructivism and proposes three criteria for meaningful learning to take place:

> (1) The student must have appropriate prior knowledge to which the new knowledge can be connected. (2) The new knowledge must be perceived as relevant to this prior knowledge. (3) The student must *choose* to make these connections (i.e., to learn meaningfully) (Ausubel, 1963; Ausubel, 1968 Ebenezer, 1992 as cited in Cooper & Stowe, 2018, p. 6057).

The instructional design principles of the flipped learning model are grounded in constructivist learning theory (Piaget, 1952) and social constructivist learning theory (Vygotsky, 1978). The design of the online component of the flipped learning model aims to support students to develop relevant prior knowledge by integrating new or modifying their existing knowledge of concepts. This in turn aims to ensure that students obtain a meaningful learning experience during the in-class component. The in-class component of the flipped learning model provides students with the additional opportunity to construct their knowledge and understanding in the social setting of the classroom by completing guided inquiry activities. This allows students to collectively co-construct their understanding of new materials with assistance from their peers or teachers.

2.3.3 Storage of knowledge and cognitive load theory

Three distinct yet interrelated theoretical models have been proposed with respect to storage of knowledge: long-term memory, short-term memory, and working memory (Cowan, 2008). While the distinction between long-term memory and short-term memory is often related to the time for which knowledge is remembered, they have distinguishing features related to "(1) temporal decay and (2) chunk capacity limits" (Aben, Stapert, & Blokland, 2012, p. 1). Long-term memory is a permanent storage of information and suggests that everyone possesses a rich set of long-term memories which can be retrieved and accessed when processing new information (Aben et al., 2012). Short-term memory refers to a temporary storage of knowledge with a limited capacity on how much information can be retained in this space. It has been proposed that working memory is derived from the concept of short-term memory and is suggested to be “an interface between perception, long-term memory and action” (Baddeley, 2003 as cited in Aben et al., 2012, p. 1).

Cowan (2008) expands on this further and provides three, slightly discrepant ways of defining working memory “as short-term memory applied to cognitive tasks, as a multi-component system that holds and manipulates information in short-term memory, and as the use of attention to manage short-term memory” (p. 1). Miller (1956) proposed the concept of capacity limit of working memory suggesting that information should be presented in ‘seven plus or minus two’ chunks. This provides valuable guidance on how to effectively design and present information to students so that newly acquired knowledge can be retained in long-term memory.

According to cognitive load theory, the process of learning imposes a load on the working memory, a limited space in which information is being used, processed, and stored (Sweller, 1988). When the amount of information and instructions exceed the mental capacity, it causes a cognitive overload and thus learning becomes hindered. To address this, it is essential to differentiate between the varying level of intrinsic, extraneous, and germane cognitive load (Chandler & Sweller, 1991; Sweller, Merrienboer, & Paas, 1998). Intrinsic load is based on the implicit delivery method of the material, extraneous load reflects the difficulty the learner will have from extracting the information from the learning materials. Whereas the germane load, refers to the process of integrating the new information with existing schemas structures stored in the long-term memory. Cognitive overload can be alleviated, if the intrinsic and extraneous loads are considered in the design and delivery of the content, thus allowing the learner to successfully process new information in their working memory.

Abeysekera and Dawson (2014) proposed that the online learning platform in a flipped learning model has the potential to reduce cognitive load. The design of the online learning platform allows students to initially access, process and construct their own knowledge at a pace that suits their individual learning needs. This gives students the opportunity to manage the constraints imposed on their working memory before attending the in-class component where the learning material presented during the in-class session builds upon the knowledge they have acquired from the online component.

2.3.4 Active learning

Bonwell and Eison (1991) provide one of the earliest definitions of active learning by stating it involves “any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing” (p. 2). Prince (2004) identifies that the “core elements of active learning are student activity and engagement in the learning process” (p. 223). Proponents of flipped learning argue that a contributing factor for the success of this instructional approach is due to its grounding in active learning pedagogies (O’Flaherty & Philips, 2015; Eichler & Peeples, 2016; Li, Lund, & Nordsteien, 2020).

Mori (2017) describes a two-way pathway where “internalization refers to understanding and acquiring knowledge while externalization refers to making use of knowledge the performance that occurs in this process” (p. 104). This two-way pathway can be observed in a flipped learning environment, the pre-learning material provides students with the opportunity to ‘internalize’ foundational knowledge needed for the in-class session at a pace that suits their individual learning needs. This is critical as Mori (2017) states that “if the internalization is of poor quality before active learning is instituted, then active learning activities tend not to be very lively” (p. 104). During the in-class session, students are given the opportunity to ‘externalize’ their knowledge through a series of active learning strategies, such as think-pair-share, informal group discussion, problem-based learning (Nilson, 2010), that take place in a social context in collaboration with peers facilitated by the instructor. In this approach, students become actively involved in the learning process compared to traditional teaching paradigms where information is often passively transmitted from the teacher.

2.3.5 Self-determination (motivation) theory

Early work by Deci and Ryan (1985) proposed two central components underlying self-determination theory: active organism and the social context. According to Deci and Ryan (1991), active organism indicates how an individual can integrate “new experiences and regulatory processes with one’s intrinsic self” (p. 239). Ntoumanis (2001) expands on this and suggests that self-determination theory encourages individuals to “achieve integration and cohesion of new ideas and interests both within themselves and with others” (p. 398). On the other hand, the social context is critical as it facilitates or hinders the individual’s ability to integrate these processes. Self-determination theory can be facilitated if the cognitive needs of an individual are taken into consideration: competence (experience mastery in knowledge, skills, behaviour and produce desired outcomes), autonomy (ownership of one's behaviour), and relatedness (sense of belonging) (Deci & Ryan, 1991; Abeysekara & Dawson, 2015). The application of self-determination theory in a learning environment "lies in the emphasis it places on students' level of motivation to be an outcome of their learning environment which can either promote or impede the satisfaction of their basic cognitive needs" (Deci & Ryan, 2008 as cited in Abeysekara & Dawson, 2015, p. 4). Abeysekara and Dawson (2015) suggested that the relationship between self-determination theory and flipped learning are mediated by different types of motivation: intrinsic and extrinsic. Intrinsically motivated behaviours "occurs without the incentive of external reward and is undertaken out of interest in the activity itself rather than the outcome of the activity" (Ntoumanis, 2001, p. 399). Whereas extrinsically motivated behaviours relate "to activities that are carried out as a means to an end and not for their own sake" (Deci & Ryan, 1991, as cited in Ntoumanis, 2001, p. 399) and often based on some external reward for completing the task.

In a flipped learning environment, students are given the flexibility to independently access the online pre-learning materials at a pace that suits their individual learning needs, thus promoting their autonomy and competence (He, Holton, Farkas, & Warschauer, 2016; Long, Logan, Waugh, 2016; Ponikwer & Patel, 2018; Xiu, Moore, Thompson, & French, 2019). The in-class component seeks to promote a learning environment mediated by social interactions and as such encourages a sense of relatedness. The degree to which students' motivation is influenced is also dependent on the course design. In some implementation of the flipped learning model, a small, graded component is assigned to the pre-learning quizzes as an incentive to encourage students to complete them (Seery, 2015). The student who chooses to complete the pre-learning materials and seeks to master the content tends to be more intrinsically motivated when compared to those students that feel they are required to complete them to be rewarded these marks (Abeysekara & Dawson, 2015).

2.3.6 Bloom's Taxonomy

Bloom's Taxonomy (1956) is a hierarchical framework used to classify educational learning objectives into three key domains depending on their level of complexity and specificity. The *cognitive domain* focuses on the mental processes required to develop knowledge and intellectual skills. The *affective domain* describes the way individuals emotionally react in and to the learning environment/context. The *psychomotor domain* refers to the physical skills and movements individuals use to complete a learning task. The research reported on in this thesis refers to the revised Bloom's Taxonomy (Anderson & Krathwohl, 2001), which rearranged the original categorises, changed the names to verb form, and created levels of cognitive processing. The revised Bloom's Taxonomy (2001) also contains six levels of cognitive processing skills represented on a continuum of increasing complexity ranging from lower order to higher order skills (see Figure 2.2). In addition to these cognitive processes, knowledge is categorised into four distinct types. *Factual knowledge* refers to the basic elements and terminology used in specific learning context. *Conceptual knowledge* focuses on the interrelationship between the basic elements and broader theories related to the specific learning context. *Procedural knowledge* relates to the specific skills or methods needed to perform a certain task. *Metacognitive knowledge* refers to the individual self-awareness about the learning process and their own cognitive ability to complete a particular task.

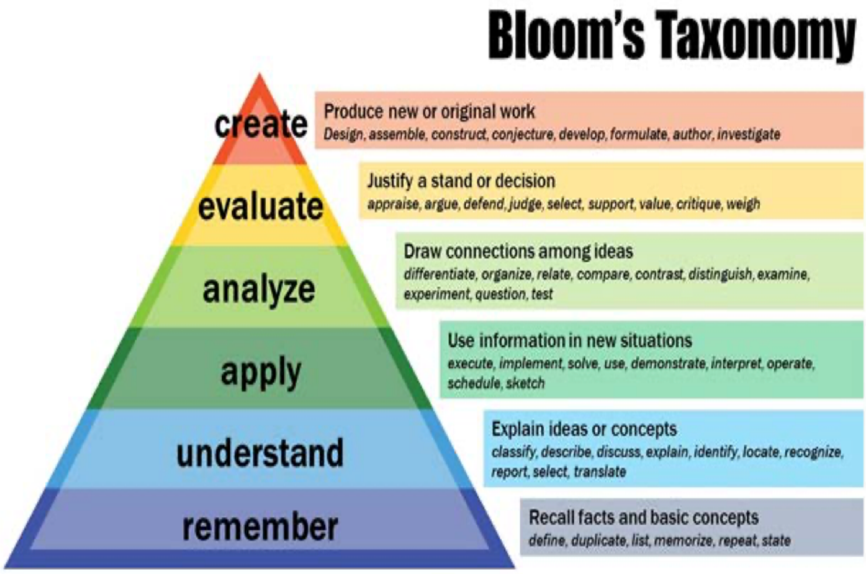

Figure 2.2. Bloom's Taxonomy hierarchical framework (extracted from Ouda & Ahmed, 2016, p. 430).

By applying Bloom's Taxonomy to flipped learning environment students are using lower levels cognitive processing skills that traditionally take place during the in-class session in an online pre-learning environment prior to the in-class session so they can develop their foundational knowledge of the course material. During the in-class sessions students are then using higher levels cognitive processing skills as they participate in active learning strategies (see Figure 2.3).

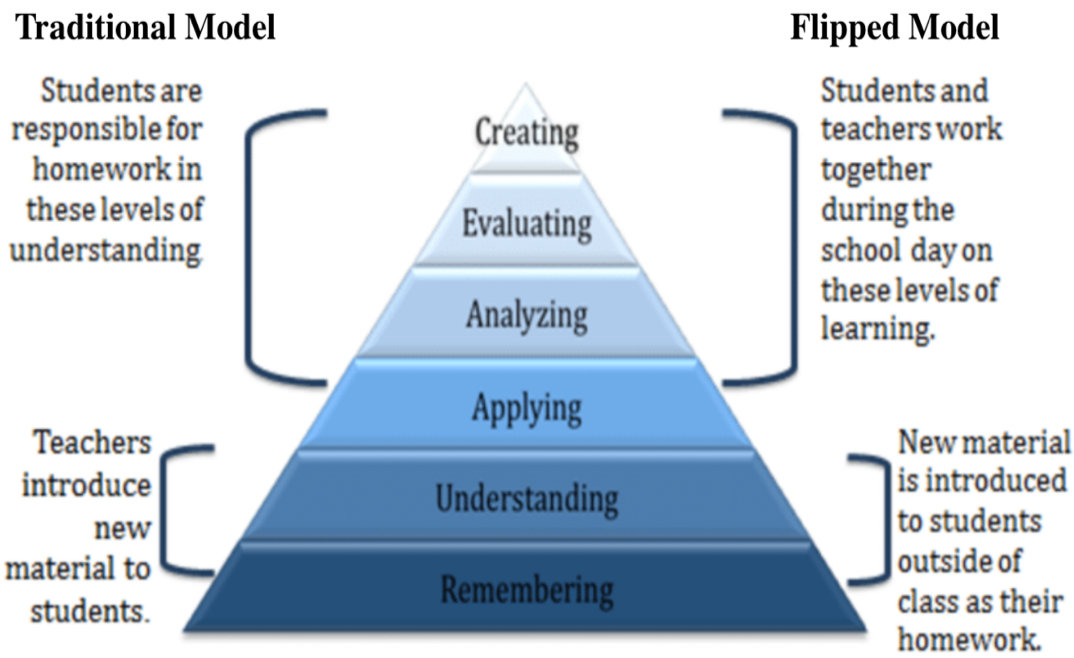

Figure 2.3. Bloom's Taxonomy hierarchical framework in a traditional versus flipped learning. Model (extracted from Ouda & Ahmed, 2016, p. 430).

2.3.7 From general to domain specific theories

Cooper and Stowe (2018) provide an extensive review of chemistry education research and how learning theories have shifted over time, to not only guide dominant learning theories such as constructivism as previously discussed, but also multilevel thought and information processing model that have informed chemistry education research.

Johnstone (1991) represented the multilevel thought in chemistry as a triangle with each corner reflecting one of the three different levels macro, sub-micro, and symbolic (see Figure 2.4). Students often experience difficulties in learning as instructions are primarily focused on the centre of the triangle and thus, they are required to simultaneously think about all three levels of chemistry. Instead, students' learning opportunities should be presented at each level before linking these multilevel thoughts to support students' conceptual and procedural understanding of chemistry. By taking this into consideration, it is possible to adjust the level of information processed by the individual and potentially reduce the gap between novice and expert learners.

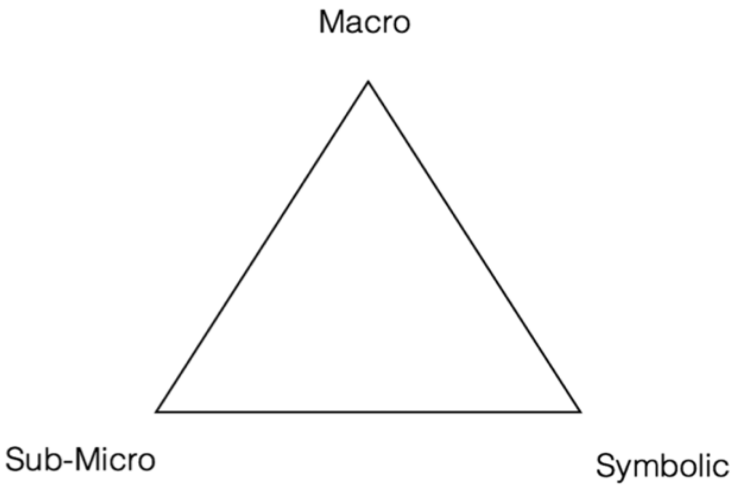

Figure 2.4. Johnstone's triangle, representing the multilevel thought in chemistry (Johnstone (1991) extracted from Cooper and Stowe, 2018, p. 6058).

Johnstone (1997) proposed an information processing model that still has a prominent impact in higher education chemistry (see Figure 2.5). In this model the incoming information is screened by a perception filter which has mainly two functions, (1) information is temporarily held in the working memory where it is processed and (2) the incoming information is processed with aid from information previously stored in the long-term memory. Johnstone (1997) notes that an individual's working memory:

> "Is limited shared space in which there is a trade-off between what has to be held in conscious memory and the processing activities required to handle it, transform it, manipulate it, and get it read for storage in long-term memory store. If there is too much to hold there is not enough space for processing; if a lot of processing is required, we cannot store much" (p. 263).

Further research extends the use of this model to explain the potential difference in information processing between novice and experts. It has been noted that "experts consider, store, and retrieve information in a different manner than novices" (Cooper & Stowe, 2018, p. 6058). To support students in effectively processing information and develop expertise "related knowledge can be consolidated in our minds into "chunks" and processed as a single unit (instead of multiple fragments)" (Cooper & Stowe, 2018, p. 6059). While it is possible to "chunk" the information to support students understanding of chemistry, it is essential to note that experts might operate at the centre of Johnston's multilevel thought triangle, whereas novices might be processing information in a fragmented manner at each corner of the triangle.

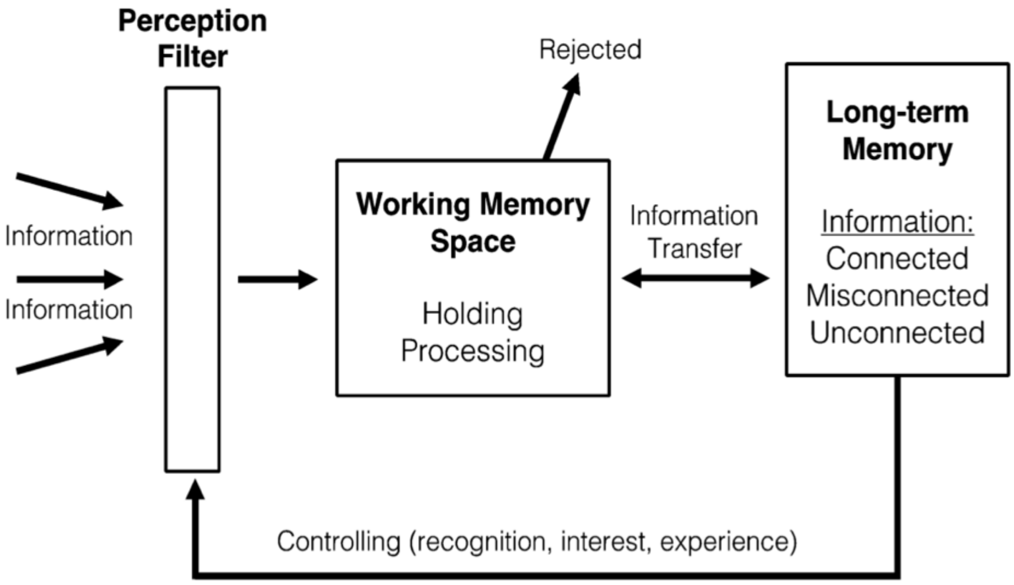

Figure 2.5. Johnstone's information processing model (Johnstone (2006) extracted from Cooper & Stowe, 2018, p. 6059).

2.4 Technology mediated learning environment

Blended learning has become a prominent pedagogical practice in higher education that fosters the learning core values of the twenty first century such as critical and analytical thinking, problem solving and collaboration (Ginns & Ellis, 2007; Trilling & Fadel, 2009; Lee, Lim & Kim, 2017; Zhao et al., 2021). Blended learning offers a flexible learning environment, an alternative to traditional teaching paradigms (Lee et al., 2017). A blended learning environment offers a combination of "face-to-face interaction and technologically mediated interactions between students, teachers, and learning resources" (Bliuc, Goodyear, & Ellis, 2007). To effectively design a blended learning environment, it is essential to determine the extent, i.e., the "right blend of learning" (Lee et al., 2017, p. 428) offered in each component of the learning environment. Blended learning does not mean merely combining the two components, but instead integrating these in a coherently linked manner to maximise the affordances offered by each component. Several researchers have criticised the typical blended learning experience which often “involves adding supplementary online discussion activities to the classroom lecture” (Lee et al., 2017, p. 428). However, in this form of blended learning, the in-class components “have remained unchanged leaving learners passive recipients, and online activities have not engaged learners as intended” (Arum & Roska, 2011; Garrison & Kanuka, 2004 as cited in Lee et al., 2017, p. 428). As such, there is an increasing need to offer a blended learning environment in which students are engaged in a series of active learning opportunities facilitated by the teacher during the in-class session, supported by technology- mediated learning that offers an individualised and flexible learning experience to accommodate for the learning needs of different types of students. A recently emerging form of blended learning that can achieve this, is flipped learning.

2.5 Flipped learning model in higher education

2.5.1 History of flipped learning

Flipped learning evolved from four key developments in educational research. Early work by Mazur (1991) as cited in Crouch and Mazur (2001) introduced peer instruction as an alternative approach to teaching introductory physics. Students were required to complete a set of readings before attending the in-class session. Following an instructor-led lecture, students were asked to individually answer conceptual questions which were then discussed with their peers before making a revised decision of their initial answer. The in-class session was facilitated by a classroom response system, an interactive technology tool that enabled the instructor to collect immediate feedback based on student’s responses. When content management systems emerged online, Baker (2000) was first to model “the classroom flip” by posting lecture notes online supplemented by online quizzes. By reducing the lecture component, the in-class sessions were designed around four key features to create an active learning opportunity. Initially, students would *clarify* any questions they may have from the assigned readings. They would then *expand* on the course content by adding knowledge from their own experience. The remaining in-class session was focused on students’ understanding and ability to *apply* course content followed by *practise* to encourage creative thinking in collaborative groups (Baker, 2000). Meanwhile, Lage et al. (2000) adopted a similar approach to Baker (2000) and proposed the concept of “inverted classroom” in a large introductory economic course to accommodate for the learning needs of different types of students. By inverting the classroom “events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa” (Lage et al., 2000, p. 32). The modern reference of flipped learning is accredited to

Bergmann and Sams (2012) as they initially used online videos to support high school students who were absent from class, and later to allow for more active learning opportunities to take place during class time.

2.5.2 Definition of flipped learning

Flipped learning takes several forms but is commonly defined as a pedagogical approach in which some portion of the didactic lecture traditionally delivered in class is moved to an independent pre-learning environment, typically delivered online (Eichler, 2022).

Instead of being exposed to content in class and then applying it as 'homework', students are initially exposed to learning course content on their own outside of class and then apply the knowledge they have acquired in-class through a range of active learning activities (Flynn, 2015; Lage et al., 2000; O'Flaherty & Philips, 2015; Seery, 2015). Since the design and implementation of a flipped learning model can vary widely across different educational context (Flynn, 2015; Seery, 2015), a universally recognised definition is provided by the Flipped Learning Network (FLN):

> "Flipped learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter." (FLN, 2014).

For educators to successfully facilitate an effective flipped learning model, the FLN (2014) proposed four pillars that are fundamental to this pedagogical approach (see Figure 2.6). A *flexible environment* is needed. This not only refers to the physical learning space but also relates to flexibility the teacher has with the type of content delivered in the various component of the flipped learning. Moreover, teachers need to implement objective assessment and evaluation tools to measure students learning in a meaningful way. A *learning culture* is required with a shift in the teaching and learning paradigms, with teachers facilitating the learning process whilst students actively engaged in the course material. *Intentional content* needs to be developed, whereby the teacher selects which content is most appropriately delivered in class and outside of class. This selection is critical as it can help develop students' procedural and conceptual understanding of course material. The role of the teacher is changed with professional *educators* having an important role during class as they continuously monitor students' progress and provide them with instantaneous feedback.

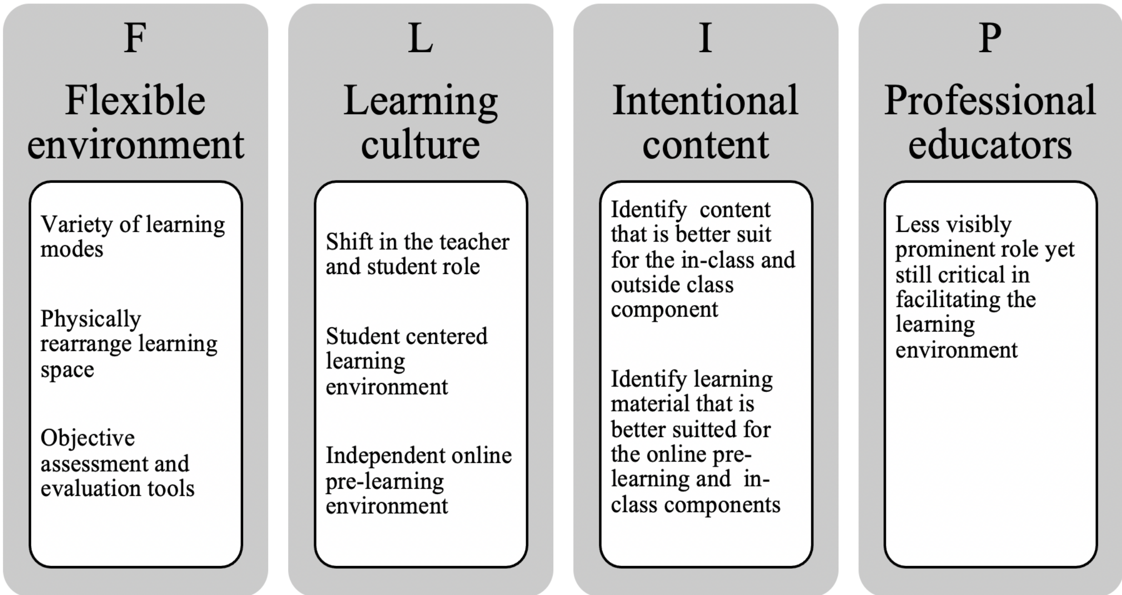

Figure 2.6. The four pillars of flipped learning (adapted from Hamdan et al., 2013).

2.5.3 Traditional learning environment versus flipped learning environment

It has been proposed that flipping the instructional design of a course creates a reversed learning experience when compared to traditional teaching paradigms (Bergmann & Sams, 2012; Hamdan, et al., 2013). Bishop and Verleger (2013) expands on this view by emphasising that flipping or inverting the classroom "actually represents an expansion of the curriculum, rather than a mere re-arrangement of activities" (p. 6).

In a flipped learning environment, there is a noticeable shift in the role of the student and the teacher when compared to a traditional learning environment (see Figure 2.7).

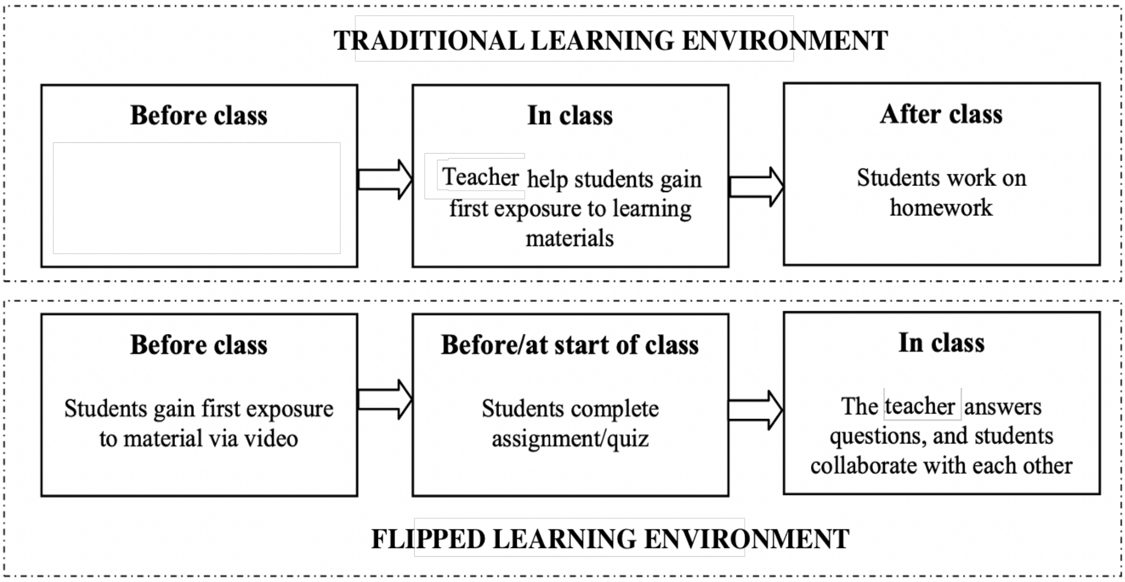

Figure 2.7. Comparison of traditional learning environment and flipped learning environment (adapted from Al-Samarraie, Shamsuddin, & Alzahrani, 2020).

In a traditional learning environment, students gain initial exposure to course content during the in-class session. In this teacher-centred learning environment, students take on the role of passive listeners whilst the teacher delivers the course material. Often, limited active learning opportunities are embedded during the in-class session and students may be often assigned homework to complete independently afterwards. In contrast, in a flipped learning environment students gain initial exposure of course content, typically delivered online, before the in-class session. During the in-class session, students are engaged in a series of active learning opportunities facilitated by the teacher. In this student-centred learning environment, students take on an active role in their learning where they participate in collaborative activities that enables them to apply their knowledge and further develop their conceptual and procedural knowledge.

2.5.4 Types of flipped learning models

The design of the flipped learning model varies widely across different educational contexts. To effectively implement this approach, a blend of in-class and online learning activities that are more focused on creating an active, personalised learning experience is critical in supporting students' engagement and learning processes. The examples in subsequent section focus on the implementation of partially or fully flipped learning models.

2.5.4.1 Traditional "fully" flipped learning model

The flipped learning model intentionally shifts content traditionally delivered in-class outside of class, which is allocated for students to complete independently in an online pre-learning environment. In-class, students engage in a series of active learning opportunities. Pioneers in flipped learning, Bergmann and Sams (2012) provide an example of a traditional flipped learning model. In their model, video lectures are assigned for students to complete as homework prior to attending the in-class session. A brief review of the key concepts from the pre-learning video is provided at the start of the in-class session and any misconceptions are addressed prior to commencing the in-class learning activities. During the in-class session, students are actively involved in constructing their knowledge whilst the teacher facilitates the learning environment. Other traditional flipped learning models encourage the use of pre-learning quizzes to assess students' levels of understanding of the content presented during the pre-learning videos (O'Flaherty & Philips, 2015). The quizzes can act as a gateway check for both students and teachers as they provide valuable feedback regarding students' level of understanding. This aids teachers in guiding the start of their in-class session by targeting specific misconceptions or misunderstanding that were identified in the performance of students in the quizzes.

2.5.4.2 Partially flipped learning model

In a partially flipped learning model, some components of the course are flipped instead of the entire course. The design and delivery of this modified model varies. For example, the partially flipped learning model adopted by Roach (2014) consisted of three weekly in-class sessions and one weekly pre-learning video. The first two in-class sessions took place at the start of the week and the content presented was mainly delivered using a traditional didactic teaching approach (lecture-based format) where students had minimal opportunity to engage with active learning activities. The last in-class session was solely dedicated for application of concepts that had been delivered in the pre-learning videos and in other in-class sessions were students engaged in a range of individual or group-based active learning activities. An alternative approach to implementing a partially flipping learning model is to select a chunk (Vidic, Clark, & Claypool, 2015) or a specific module (Burgoyne & Eaton, 2018) from the course in which the content can be effectively delivered in the pre-learning environment with meaningful active learning activities embedded in the in-class session to support and build students conceptual understanding.

2.5.5 Components of a fully or partially flipped learning model

2.5.5.1 Online component

The types of online pre-learning materials in flipped learning models vary across different educational contexts, and may include assigned readings, web-based tutorials, discussion forums, animations, pre-recorded lectures. The most prevalent modalities used, however, are videos and quizzes (O'Flaherty & Philips, 2015). Most of the pre-learning videos use screencast capturing audio narration over PowerPoint slides which are delivered through YouTube or a learning management system (LMS). The length of the screencast varies, often kept as relatively short segments to optimise students' engagement with the learning process (Clark, Nguyen, & Sweller, 2006). The design of the pre-learning videos often adheres to the principles outlined in the cognitive theory of multimedia learning which suggest that combining both visual and verbal representation of abstract construct supports students' learning experience (Baggett, 1984). After viewing the pre-learning videos, students typically complete pre-learning quizzes and in some cases are incentivised with a small portion of the course grade (Flynn, 2015; Seery, 2015). The format of the pre-learning quizzes differs based on the intended learning outcomes and can be structured in a mastery format to allow for multiple attempts. The intention of the pre-learning quizzes is to provide students with the opportunities to assess the knowledge they have acquired from the pre-learning videos and receive instantaneous feedback and target support to address any potential misunderstanding in course content before the in-class session (Fautch, 2015). An alternative to students completing a pre-learning quiz after viewing the pre-learning video or at the beginning of the in-class session is to assign problem solving questions where students can further demonstrate the knowledge they attained and provide teachers with valuable instantaneous feedback regarding their level of understanding of course content.

Fewer studies have reported on the inclusion of post-learning materials to further consolidate the in-class learning materials. For example, in Flynn (2015) proposed the use of post-class assignments in their flipped chemistry courses to further consolidate, and in some cases extend students' understanding in a deeper manner.

2.5.5.2 In-class component

The in-class session often begins with a teacher-led 'mini-lecture' that addresses any difficulties students may have experienced with the pre-learning materials followed by a range of individual or group-based active learning activities (Fautch, 2015; O'Flaherty & Philips, 2015; Seery, 2015). While a variety of active learning activities are reported on in the flipped learning literature, several studies, including ones in the field of chemistry education, have focused on the use of Problem-Based Learning (PBL), Peer-Led Team Learning (PLTL) and Process Oriented Guided Inquiry Learning (POGIL). For example, in the instructional approach POGIL, students work collaboratively in small groups facilitated by the teacher to guide them through three phases of the learning cycle. The first phase is focused on exploring where students try to identify trends or patterns in the concept provided by the teacher. In the second phase, students propose a new concept using the trends or patterns they have identified in the first phase. In the last phase, students apply the knowledge they have discovered to a new situation, to further develop their conceptual and procedural understanding.

Despite the use of these student-centred instructional approaches, the formative and summative assessment embedded in the flipped learning model reported in the existing literature in large is still focused on measuring students' understanding by course grades or retention rates which are reflective of traditional performance metrics (Eichler, 2022). Flynn (2015) offers an alternative approach to measure students' learning gains by purposefully designing the in-class learning in accordance with the course learning objectives to address higher cognitive processing skills from Bloom's Taxonomy.

2.5.6 Factors that influence students' learning

2.5.6.1 Conceptualisation of engagement

There is an increased recognition that student engagement is an essential prerequisite for learning, given its potential to improve academic achievement and retention (Fredricks, Blumenfeld, & Paris, 2004; Fredricks, Filsecker, & Lawson, 2016; Wang & Fredricks, 2014). Conceptualisation of engagement varies considerably across different education context. Therefore, there is a strong emphasise in the literature to clearly define engagement to avoid any potential overlap with other motivational and cognitive constructs (Fredricks et al., 2016). A commonly cited definition is the one proposed by the seminal work of Fredricks et al. (2004) which conceptualised engagement as a multidimensional construct that encompasses three distinct yet interrelated dimensions: behavioural, emotional/affective, and cognitive engagement.

More specifically, Fredricks et al. (2004) state that:

> “Behavioural engagement draws on the idea of participation; it includes involvement in academic and social or extracurricular activities and is considered crucial for achieving positive academic outcomes and preventing dropping out. Emotional engagement encompasses positive and negative reactions to teachers, classmates, academic, and school and is presumed to create ties to an institution and influence willingness to do work. Finally, cognitive engagement draws on the idea of investment; it incorporates thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills” (p. 60).

Bond et al. (2020) draw from the existing literature several indicators of student engagement and disengagement for each of the three dimensions: behavioural, emotional/affective, and cognitive (see Table 2.1 and Table 2.2). These indicators vary on a continuum depending on students “activation (high or low) and valence (positive or negative)” (Pekrun & Linnenbrink-Garcia, 2012, as citied in Bond et al., 2020, p. 4).

Although most of the reported literature draws upon the work of Fredricks et al. (2004) on the conceptualisation of engagement, more recent developments have broadened the dimensions of engagement. For example, Reeve and Tseng (2011) expanded on the conceptualisation of engagement to include an agentic dimension which refers to the actions students proactively, intentionally, and constructively take towards the set of instructions provided by teachers during the learning process. Linnenbrink-Garcia et al. (2011) proposed social (social-behavioural) engagement as another dimension which focuses on student’s interaction and collaboration with peers and teachers inside and outside of the learning environment.

Table 2.1. Some indicators of student engagement (modified from Bond et al., 2020).

Behavioural Engagement	Emotional/Affective Engagement	Cognitive Engagement
Effort	Interest	Self-efficacy
Attendance	Attitude	Self-regulation
Task completion	Course value	Deep learning
Access course content	Satisfaction	Integration of ideas
Time on task (persistence)	Confidence	Focus on conceptual understanding
Participation (in class and online)	Relevance	Critical and analytical thinking skills
Interaction (peers, teachers, content, and technology)	Sense of belonging and connectedness	Personalised and sophisticated learning strategies

Table 2.2. Some indicators of student disengagement (modified from Bond et al., 2020).

Behavioural Disengagement	Emotional/Affective Disengagement	Cognitive Disengagement
Inattentive	Dislike	Unwilling
Procrastination	Disinterest	Avoidance
Underprepared	Boredom	Disconnect of ideas
Non-Attendance	Frustration	Surface learning
Task incompletion	Overwhelmed	No specific learning strategies

Whilst student engagement is critical in any learning environment, Henrie et al. (2015) systematic review focused on measuring student engagement in technology-mediated learning environments in higher education. They reported that quantitative self-reported instruments, in the form of surveys, were the most common methods used followed by qualitative observational measures including screen capture observation of students' interaction, interview or focus groups. Fewer studies combined quantitative observational measures in the form of learning analytics to track students' engagement level with follow up qualitative measures to gather a holistic understanding of engagement. A more recent systematic review by Bond et al.

(2020) reported that self-reported instruments were also predominately used to measure students' engagement in educational technology courses in higher education. In a follow up systematic review by Bond (2020), self-reported instruments were also commonly used to measure students' engagement in flipped learning course in K-12 educational contexts. Across these systematic reviews, it was noted that although self-reported instruments provide valuable insights, the results provided a narrow view of engagement as they tend to mainly focus on behavioural engagement with limited attention being placed on the emotional and cognitive dimensions (Fredricks et al., 2014).

The National Survey of Student Engagement (NSSE) and the Australasian Survey of Student Engagement (AUSSE) are the most frequently used questionnaires to measure students' engagement from a behavioural lens in higher education (Kahu, 2013). The NSSE measures engagement using five scales: (1) level of academic challenge, (2) active and collaborative learning, (3) student-faculty interaction, (4) enriching educational experience, and (5) supportive learning environment. The AUSSE builds on the NSSE and adds an additional engagement scale related to work integrated learning. Despite their popular use and their claims to be empirically derived from good psychometric measures, several studies have critiqued their validity and the way NSSE and AUSSE conceptualised and measured engagement specially since they focus on the behavioural dimension of engagement rather than the complex multidimensional nature of students' engagement (Henrie et al., 2015; Kahu, 2013). Moreover, Fredricks and McColskey (2012) conducted a recent review of self-reported measures that revealed items measuring the behavioural, emotional, and cognitive dimensions are used inconsistently across questionnaires which makes comparison of research findings difficult across studies.

One possible way to overcome this is to develop and validate a comprehensive scale or index that encompasses the multidimensional constructs of engagement. Although scales and indexes are used interchangeably, and both are composite measures, they possess notable differences (Babbie, 2012). An index can be constructed by accumulating scores assigned to individual indicators. A scale assigns scores based on a response pattern and takes into consideration different intensities of those indicators, where some indicators are relatively weak, and others are strong. For example, Deng et al. (2020) developed and validated a Massive Open Online Courses (MOOCs) scale to measure students' engagement across four dimensions: behavioural, cognitive, emotional, and social engagement. The scale development process included four phases: (1) item generation and reduction whereby existing construct in the literature were reviewed and relevant measures were selected, (2) item refinement was carried out to eliminate redundant items and generate new ones, (3) construct validity was conducted to examine the purity of the items, (4) construct validation was carried out to measure the reliability and validity of the items.

Tasker et al. (2003) constructed an engagement index to quantitatively measure student's engagement with online chemistry modules. In their study engagement was defined using measurable tracking data based on their interaction patterns with the online modules. The engagement index was comprised of five parameters:(1) completion time for module, (2) time spent on both introductory screens, (3) time spent on experimental set-up screen, (4) time spent between opening screen and selecting an answer and (5) access to rules. Tasker et al. (2003) attempted to classify students based on their level of engagement rather than construct a scale of engagement. Students were assigned a score from 0-2 depending on their level of engagement (not engaged = 0, engaged = 1 and very engaged = 2) for each parameter which were then added to get an overall engagement index score. The cut-off values for the three engagement levels were subjective and derived from the students' interaction data with each of the parameters. The reliability of the developed engagement index was validated in two ways, firstly by measuring the correlation between the engagement index score with an independent parameter not included in the original design of the index and secondly by comparing the engagement index score with students' personal recollection of their interaction with the online modules.

Although these proposed methods provide alternative quantitative measures to potentially examine engagement, there is a strong emphasis in the literature to combine the use of quantitative and qualitative measures to gain a holistic understanding of students' engagement (Fredricks et al., 2016).

2.5.6.2 Approaches to learning

Substantial research has been conducted on students' approaches to learning in higher education. Broadly, an approach to learning reflects the student's intention when starting a task and the learning processes and strategies they adopt to complete the task (Jovanović et al., 2017). The seminal work by Marton and Säljö (1976) used a phenomenographic research approach to examine from the student's perspective their approach to learning whilst reading academic articles and texts followed by answering a series of related comprehension questions. Differences between students' approaches to learning were analysed qualitatively based on students interview responses. Based on their results, students' approaches were classified into two main levels of processing: surface and deep. Surface learning processes were displayed by students that relied on rote learning and memorisation of materials, whereas those that adopted deep learning process focused on seeking meaning and relating concepts with previously acquired knowledge. Subsequent research identified a third level of processing, the achieving or strategic approach where students are extrinsically motivated to adopt a surface or deep approach towards their learning to maximise their academic performance (Biggs, 1987; Kember & Leung, 1998; Ramsden, 1979). Entwistle (2000) outlines in more detail the characteristics of these three different approaches to learning (see Table 2.3).

Table 2.3. Defining features of approaches to learning (extracted from Entwistle, 2000).

Surface approach	Strategic approach	Deep approach
Passively reproduction Intention – merely to cope with course requirements by:	*Reflective organising Intention* - to achieve the highest possible grades by:	*Actively transforming Intention* - to understand ideas for yourself by:
Treating the course as unrelated bits of knowledge	Putting consistent effort into studying	Relating ideas to previous knowledge and experience
Memorising facts and carrying out procedures routinely	Managing time and effort effectively	Looking for patterns and underlying principles
Finding difficulty in making sense of new ideas presented	Finding the right conditions and materials for studying	Checking evidence and relating it to conclusions
Seeing little value or meaning in either courses or tasks set	Monitoring the effectiveness of ways of studying	Examining logic and argument cautiously and critically
Studying without reflecting on either purpose or strategy	Being alert to assessment requirements and criteria	Being aware of understanding developing while learning
Feeling undue pressure and worry about work	Gearing work to the perceived preferences of lecturers	Becoming actively interested in the course content

Further research expanded on the initial conceptualisation of Marton and Säljö (1976) by developing self-reported questionnaires to quantify students' approaches to learning. Entwistle and Ramsden (1983) originally developed the Approaches to Studying Inventory (ASI) with several versions adapted over the years including the Revised Approaches to Studying

Inventory (Entwistle & Tait, 1995), Approaches and Study Skill Inventory for Student (Tait, Entwistle, & McCune, 1998) and Approaches to Learning and Studying Inventory (Entwistle & McCune, 2004). The original ASI classifies students according to four orientations of studying: meaning, reproducing, achieving orientation, and non-academic orientation. Students with a meaning orientation are intrinsically motivated and are focused on understanding and relating knowledge. Students with a reproducing orientation are extrinsically motivated and rely on rote learning strategies to build their understanding. Students with an achieving orientation are aware of the learning requirements and use organised study methods with the sole purpose of achieving their goal. Students with a non-academic orientation possess lower levels of motivation and are less organised in their study methods.

Biggs (1987) initially proposed a 43-items Study Process Questionnaire (SPQ) that conceptualised the three approaches to learning (surface, deep, and achieving approach) further into two main sub-components: motive and strategy. Students that adopt a surface approach towards learning are extrinsically motivated. Their learning strategies are limited to rote learning as they seek to put minimal time and effort into the learning process. Students that adopt a deep approach towards learning are intrinsically motivated. Their learning strategies focus on seeking meaning to enhance their level of understanding. The motive of students that display an achieving approach is to maximise their academic performance, while being strategic with their use of time and space as their learning. Further research by Biggs et al. (2001) revised the original SPQ and refined it to 20 items in the R-SPQ-2F questionnaire. The R-SPQ-2F questionnaire focused on only measuring students' surface and deep approaches while also taking into consideration the motive and strategy sub-components. It is critical to note that students cannot be categorised as "surface" or "deep" learners based on their SPQ or R-SPQ-2F questionnaire responses. Students' approaches to learning are not stable psychological traits but instead are influenced by both individual factors and the teaching context. Thus, students' approaches to learning are relational, suggesting that a student can vary their approach depending on the nature of the task and the way they perceive the task in each context.

Biggs's (1993) presage, process, and product model (3P) provides a framework for understanding the role of students' approaches to learning in an educational context (Figure 2.8). In the 3P model, the presage stage represents the characteristics the students initially possess which include background knowledge, ability, and their preferred approach to learning.

In the presage stage individual students can be influenced by several factors from the teaching environment. These then influence the process stage which reflects students' behaviour in the learning environment and their adopted approach while learning. The last stage is the product which reflects the effect of students' adopted approach to learning and strategies on their academic performance. The 3P model reflects several direct and indirect factors that can influence students' behaviour and as a result their academic performance.

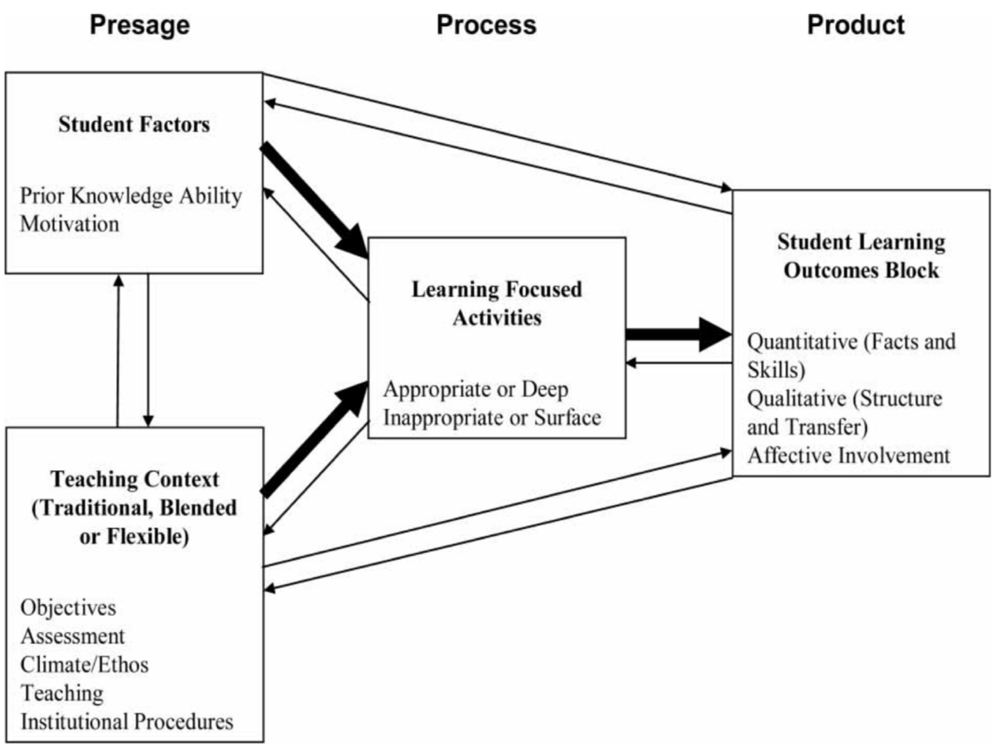

Figure 2.8. Bigg's 3P model (extracted from Hamilton & Tee, 2013, p. 751).

The review by Baeten et al. (2010) highlighted several factors that encourage and discourage students to adopt a deep approach to learning in student-centred learning environment. Their findings revealed that students varied their approach to learning according to disciplines, with the deepest approach generally observed in human science. It was noted that teachers played a critical role in stimulating students towards the use of a deep approach to learning. Students' initial approach appeared to be a main factor in determining which approach they will adopt whilst learning. Gijbels et al. (2008) found that the stronger the students' initial approach, the less likely they are to change their approach. In addition, it was noted that a student's motivation, self-confidence, and self-efficacy are key contributing factors in influencing their adopted approach to learning. The main contextual factor that appeared to influence students' approaches to learning is their perceived course value. Students that were satisfied with the course quality were observed to have a general tendency towards adopting a deep approach to learning. These results, in conjunction with the 3P model, highlight the complex processes that are involved in encouraging or discouraging students from adopting the desired approach to learning in an educational context.

2.5.7 Impact of flipped learning on academic performance and failure rate

There is increasing evidence that a flipped or partially flipped learning model has the potential to yield significant gains in academic performance and reduction in failure rates when compared to traditional didactic teaching paradigms across a range of disciplines and educational context. A meta-analysis by Cheng et al. (2019) evaluated the effect of flipped learning as an instructional strategy on students' learning outcomes across 55 studies and found an overall small significant Hedge's effect size of $g = 0.19$ when compared to traditional teaching methods. The effect sizes varied significantly across disciplines, with the smallest effect size observed in Science, Technology, Engineering and Mathematics (STEM) courses. More recently, a comprehensive meta-analysis by Bredow et al. (2021) across 317 studies evaluated the efficacy of flipped versus traditional STEM and non-STEM courses and found small to moderate positive effects on academic performance and intra-/interpersonal skills, and small positive effects on satisfaction in flipped courses. Educational context was identified as a leading factor responsible for the observed variability in the efficacy of flipped learning outcomes in higher education. Similar findings are reported in a meta-analysis by Låg and Sæle (2019) where the difference in the effect of flipped learning was observed to be more pronounced in non-STEM courses when compared to STEM courses. Due to their broad classification of disciplines, however, it was not feasible to identify differences within specific non-STEM and STEM courses.

The effect of flipped learning on students' academic performance in chemistry education is further explored with noticeable variation reported in the literature. The meta-analysis by Rahman and Lewis (2020) of evidence-based instructional practise in undergraduate chemistry education covered 15 flipped classroom implementations. They observed, using Hedge's effect size, a small to medium positive effect size with respect to students' academic performance.

The three-year longitudinal study by Weaver and Sturtevant (2015) of first year general chemistry courses reported significant improvements in the American Chemical Society (ACS) exam scores in the flipped course format when compared to a traditional course format. In a broader study conducted by Flynn (2015), significant improvements in course grades and decreased failure rates and D's, F's, and withdrawal (DFW) rates were observed in four flipped organic and spectroscopy courses when compared to their historical course data pre-flipped model implementation. In contrast, Yestrebsky's (2015) parallel study found no significant difference in the ACS exam score between first year general chemistry courses taught in a flipped versus a traditional lecture-based format. In the flipped format course, however, significantly higher overall course grades were noted but no changes in the lower grade merits (D's and F's).

A recent systematic review by Bancroft et al. (2021) noted that studies examining the impact of the flipped learning model on the academic performance in undergraduate chemistry courses have mainly focused on the broader student population with limited emphasis being placed on the academic diversity of the student population within a course. Eichler (2022) built on this notion and suggested several studies that have shown the impact of the flipped learning model to be more pronounced for less academically prepared students. Ryan and Reid's (2016) year-long parallel controlled study in an undergraduate general chemistry course found no significant difference in exam performance between the flipped and traditional course format. In the flipped course format, however, significant improvements in exam grades and decreased DFW rates were noted for the bottom third of student population as measured by their ACS pre-test score. In another study, Crimmins and Midkiff (2017) implemented a flipped learning model in an undergraduate organic chemistry course and observed improvements in learning outcomes for all students, but those at the lowest academic achievement levels appeared to experience the most gains. Similar findings were also observed in Cormier and Voisard (2018) undergraduate organic chemistry course where significantly higher course grades were observed compared to historical course data. Moreover, they observed that the flipped format had the greatest effect on performance for "low-achieving" students as categorised by their academic ability. Differences in performance were suggested to be related to students' varying levels of engagement with the active learning activities. Differences in performance may have also been influenced by students' level of interaction with the pre-learning materials, however, this was purposefully not measured as it was assumed to be the responsibility of the students to be come prepared to the in-class sessions.

Further, even partially flipping undergraduate chemistry courses can have a significant and positive impact on students' academic performance. Shattuck's (2016) controlled parallel study on a partially flipped organic course flipped a third of the content that focused on challenging concepts. A significant improvement was observed in the exam questions related to the topics delivered in the partially flipped format and there was a noticeable increase in the A and B grades and a decrease in withdrawal rates. More recently, Bokosmaty et al. (2019) observed significant improvements in higher grades distribution across three introductory undergraduate chemistry courses with lower or relatively unchanged failure rates when compared to historical course data.

In another study, He et al. (2018) found that a partially flipped model in an undergraduate chemistry course had a small effect on the exam performance of the current course, but positive effects in performance were eventually transpired in the subsequent course offering. These results align with those of Casasola et al. (2017) who found that students in a flipped chemistry course to achieve higher grades in the subsequent chemistry course when compared to those in the traditional course format in the same semester. However, He et al. (2018) extended on this and suggests that adopting a partially flipped learning model has the potential to bridge the achievement gap between various groups of students. They reported that "academically weaker" students were perceived to have benefited much more from this instructional approach compared to academically stronger students where their performance remained relatively constant.

Despite the varied reported effects on students' academic performance across different disciplines, it remains unclear which feature(s) of the flipped or partially flipped model result in the desired positive outcomes (Bancroft et al., 2021; Eichler, 2022; O'Flaherty & Philips, 2015). The lack of clarity may in part be related to the variations in implementation of the instructional design and the types of learning activities embedded in each of the pre-learning and in-class component. For example, a study by Eicher and Peeples (2016) in a large introductory chemistry course found a significant improvement in the course grade point average (GPA) of students in the partially flipped format compared to students in a non-flipped course format. No significant differences, however, were observed in final exam scores between the two formats. It was proposed that the interactive learning activities in the in-class component may not be the only contributing factor that improved students' learning gains. Although it was not feasible to isolate the direct effects of the various components of the model, it was hypothesised that the online pre-learning materials may have had a greater impact on students' academic performance. More recently, Lee and Choi (2019) observed, in a life science course, a strong positive correlation between the two components of the flipped learning model. A strong positive correlation was also observed between the pre-learning component and final learning outcome. This relationship was almost twice when compared to the effect of the in-class learning component on learning outcomes.

2.5.8 Impact of flipped learning on engagement

Several studies have examined the effects of a flipped or partially flipped learning model on students' engagement and learning outcomes, however, few studies have been conducted in higher education chemistry courses. Student engagement is characterised by "the quality of efforts students themselves devote to educationally purposeful activities that contribute directly to desired outcome" (Hu & Kuh, 2002, p. 555). Student engagement is conceptualised as a multi-dimensional construct that encompasses three components: emotional, cognitive engagement and behavioural (Fredricks et al., 2004). Although emotional and cognitive engagement have an important influence on academic performance and achievement (Wang, 2017), behavioural engagement has been identified as the "strongest indicator of success in terms of learning outcomes" (Lee, Park, & Davis, 2018).

Seery (2015) evaluated students' engagement with the various components of a flipped undergraduate chemistry course. Analysis of students access to the pre-learning materials showed high levels of engagement with overall 92% of students viewing the pre-learning videos and completing the associated pre-learning quizzes. To quantify students' cognitive engagement with the in-class component, questionnaire responses were gathered on four questions from the students whilst they were working through the assigned work to evaluate in real time their engagement levels. Responses from three of the questions indicated that students were generally engaged, were perceived to be applying effort and were content to continue working on these assigned tasks. Students strongly disagreed that they were unaware of their surroundings, which is expected given the active nature of the in-class component. It was proposed that future research should investigate the relationship between engagement and learning outcomes and which feature(s) of the model may lead to improved learning outcome.

A broader study conducted by Burke and Fedorek (2017), in a crime control course, compared students' engagement across traditional, online and flipped formats. It was anticipated that students in the flipped course format would report higher levels of engagement as they were actively engaged in the learning process during the in-class component. However, this was not the case. Students in the flipped format reported lower levels of engagement, developed fewer personal skills, and applied fewer critical and analytical thinking skills compared to those in the other formats. Different findings were observed by Subramaniam and Muniandy (2019) in a computer science course where students self-reported higher levels of engagement across the four constructs of engagements (behavioural, agentic, cognitive, and emotional) in the flipped format of the course. However, no significant difference in terms of students self-reported engagement levels were observed when comparing the flipped to the traditional course format. It was suggested that a potential factor that may have led to the observed results may be related to the instructional design adopted in these course and further refinements related to the online pre-learning lectures such as adding subtitles or captions might be needed to better support students learning experience.

Limited research has examined the relationship between students' engagement and learning outcomes in the online component, with the majority focused on the in-class component of the flipped learning model. Smallhorn (2017) found that the flipped learning model implemented in a genetics, evolution and biodiversity course led to an increase in students' engagement as measured by their attendance and submission rates of assigned tasks. Despite improved levels of engagement, no significant differences were observed in paired answers to multiple choice questions as classified by Bloom's Taxonomy when comparing before and after flipped model implementation. Further analysis showed no significant differences in the final course grade between the flipped and historical course data. Smallhorn (2017) suggested that a flipped learning model creates a "cultural shift towards a more engaged learner" (p. 51) instead of measurable academic learning gains.

A more recent study by Meyliana et al. (2022) revealed that a flipped learning model implemented in an undergraduate information technology course resulted in improved learning outcomes when compared to a traditional course format. No strong causal links were observed. It was proposed, however, that higher levels of engagement in-class may have been responsible for the improved mid-term and final course exam scores. Although limited research has explored the effect of students' engagement with the pre-learning materials, it is perceived to be a critical feature in providing students with the foundational knowledge needed for the in-class sessions where they actively engage in building their procedural and conceptual understanding of course content (Cormier & Voisard, 2018; Ryan & Reid, 2016).

Lee et al. (2018) measured students' self-reported responses on their pre-class and in-class engagement in a general biology or chemistry flipped learning course and its impact on different types of learning outcomes. The overall learning outcomes of the courses were significantly influenced by all three multi-dimensional constructs of engagement with the greatest impact observed from the affective engagement domain. The most influential affective factors were students' attitude and perceived value of the flipped learning environment.

For content/learning related outcomes of the courses, behavioural engagement was observed to have the greatest impact followed by affective engagement. No significant differences were noted for the cognitive engagement domain. It was noted that the main behavioural factor that led to these noticeable trends in content/learning related outcomes was students' persistent effort with the course material. All the reported findings related to flipped learning outcomes appeared to be influenced by the students' pre-class and in-class engagement levels.

To examine the relationship between students' behavioural engagement and achievement, most of these studies have primarily relied on students' self-reported data of engagement in the form of questionnaires or think-aloud methods (Jovanović et al., 2017). While these studies provided valuable insights, self-reported perceptions of behavioural engagement may often lead to an inaccurate recall of events of their learning as they are not captured in real-time (Hsiao, Huang, Huang, Lu, Yin, & Yang, 2019). An alternative approach that provides direct evidence of students' "actual" behaviour is the use of learning analytics (Jovanović et al., 2017; Wang, 2017; Wang, 2019). The data obtained through these measures supplement the current understanding of how online behavioural engagement with the online learning platform may affect achievement.

Preliminary research by Wang (2017) developed an exploratory behavioural model using the partial least square structural equation modelling (PLS-SEM) method to reveal how students' online behavioural engagement affects their achievement in a flipped learning environment. Wang's (2017) research is a preliminary contribution to the field, as learning analytics were used to analyse data extracted from the courses' LMS instead of self-reported measures to gather data on students' behavioural engagement. The design principles of the flipped learning model adopted by Wang (2017) were grounded in Merrill's framework (2013) that uses a problem-centred learning approach to activate, demonstrate, apply, and integrate information. Moreover, self-reflection and self-assessment learning activities were embedded in the design of the flipped learning model to further promote behavioural engagement with the online learning material and promote students' engagement with the problem-solving activities. It was observed that students' engagement with this problem-centric framework had a significant positive effect on formative assessment and students' overall academic achievement.

2.5.9 Impact of flipped learning on behavioural pattern

Numerous studies have identified context specific trends related to the pre-learning videos and pre-learning quizzes used in a flipped or partially learning environment. However, there is limited empirical evidence focused on examining the diverse distribution of online behavioural patterns with the pre-learning materials and its potential correlation with academic performance.

Dazo et al. (2016) attempted to address the gap in the literature by using objective data instead of self-reported measures from students to gain an understanding on their video-viewing behaviours in a flipped computer programming course across three different offerings. When comparing the percentage of pre-learning videos *accessed* over a semester, noticeable differences were observed between the courses with some having high access rates whilst other having a lower one. However, this is a binary measure that only indicates whether a student has accessed the pre-learning video instead of the length of them viewing it. Thus, *content coverage* was used to report on the duration spent watching the pre-learning videos, but no clear patterns were observed across course. Another important measure was *punctuality* which monitored when students accessed the pre-learning video relative to the start of class with noticeable variations across courses. The last measure used was *distribution* of pre-learning videos which revealed that most students watched the pre-learning video once or not at all. A significant relationship was observed between students' *punctuality measure and their academic performance.* Students that accessed the course content for the first time prior to the in-class session performed better than the remaining students. Variation across the three courses were proposed to be related to sociotechnical factors. Favourable behavioural patterns were observed for one of the three courses due to the following adjustments: (1) introduction of a new course requirement to create one post per pre-learning video led to an improvement in content coverage, (2) personalised feedback related to which segments of the pre-learning had and not been viewed, (3) automated reminders to view pre-learning videos prior to class and complete any overdue tasks. Although this study provides empirical data related to students' interaction with the pre-learning videos and its effect on academic performance, further analysis investigating interaction *within* the pre-learning video can potentially identify different forms of engagement adopted by the students.

In contrast, Beatty et al. (2019) found no significant relationship between video-viewing patterns and academic performance in an introductory management flipped course. In their study, students were categorised as either low or high performing in relation to the median score in each of the three exams and overall course grade. Whilst no significant results were observed, it was noted that high performing students in the overall course grades watched all the pre-learning videos. When comparing video-viewing patterns with performance in the second and third exam, the number of low-performing and high-performing students not watching the pre-learning videos drastically increased compared to the first exam. It was proposed that students may not have expected that watching the pre-learning videos would be helpful for their exam. To enhance students' video-viewing behaviour several suggestions were made: (1) present important content at the start of the videos, (2) access important content only from the videos, (3) build interactive component such as a quiz into video, (4) choice selection of video based on their learning needs.

Long et al. (2019) found that the use of interactive pre-learning videos instead of the 'typical' pre-learning video structure had a significant impact on students' academic performance, self-efficacy, and cognitive and metacognitive skills in a flipped pre-service teaching course. The design of the interactive pre-learning videos was based upon the Knowledge Integration Theory, embedding probing problems at various intervals enabled students to integrate their prior knowledge and further develop their conceptual understanding of the course material. It was proposed that the use of interactive pre-learning videos can address the traditionally perceived shortcomings of the pre-learning material being passive in nature. Creating interactive pre-learning experiences can thus improve students' in-class engagement level which potentially leads to improved academic performance.

A more recent study by Naibert et al. (2020) noted that variation in students' video-viewing behaviours may be related to the structure of the in-class environment. For example, students in courses where the dominant behaviour was responding to teacher-led questions were less likely to watch the pre-learning videos compared to courses where the dominant behaviour encourages group work interaction between students. Although the results do not report on the nature of the pre-learning videos used, they focused on categorising students' self-reported engagement through the Interactive-Constructive-Active or Passive (ICAP) framework. According to this framework, *passive* is the lowest mode of engagement and refers to students only receiving information. An *active* mode includes students repeating the presented information. A *constructive* mode relies on students producing new information based on what is presented, and an *interaction* mode encourages students to converse about the information. Most of the students displayed active and constructive engagement behaviours. This supports O'Flaherty and Philips (2015) claim that suggests students are less inclined to engage in pre-learning materials that lack interactivity, formative feedback and are not logically linked to the in-class material. Another factor that also encourages students' engagement with the pre-learning videos is the flexibility in access and the relative short length to manage students cognitive load (Abeysekera & Dawson, 2014; O'Flaherty & Philips, 2015).

Further insights about students' online behavioural engagement were reported in a preliminary study by Lacher and Lewis (2014) which mainly focused on the impact of the pre-learning quizzes on academic performance in a flipped undergraduate computer science course. It was observed that completing the pre-learning quizzes did not lead to significant improvements in students' course grades. However, higher aptitude students tend to benefit more from having pre-learning quizzes than lower aptitude students. Several factors contributed to the observed results; pre-learning quizzes are used as a 'gateway' tool to assess students' level of understanding of course material presented in the pre-learning videos. By completing the pre-learning materials, students improve their preparedness level for the content presented in the in-class sessions. Despite these perceived benefits, it was proposed that "higher aptitude" students tend to benefit more from having pre-learning quizzes as they are usually less inclined to watch the pre-learning videos. Thus, having pre-learning quizzes would encourage them to complete all the required learning activities. The design of the pre-learning quizzes, specifically the multiple-choice nature of the questions, leads to more surface learning rather than facilitating deep learning which may explain why lower aptitude students may not have benefited equally. It was suggested that future implementation of the pre-learning quizzes should include a variety of question formats, such as filling in blanks or short answer questions. In a follow up study, Lacher and Lewis (2015) observed similar results but extended the research further by exploring how different approaches to learning (deep, surface, and strategic) impacted students' academic performance. It was observed that the pre-learning quizzes improved the grades of students who had a tendency towards adopting a surface approach sufficiently to be aligned with those that tended to adopt a deep learning approach. No detailed analysis, however, appears to have been carried out to explore this further.

Previous studies have almost exclusively focused on examining students' behaviours with individual components of the pre-learning materials and its effect on academic performance. Other research has not only considered this but also provided a more profound understanding of students' overall online behavioural patterns with all the pre-learning materials and its impact on academic performance. Jovanović et al. (2017) used learning analytics to examine learning strategies and behavioural patterns of students in a flipped undergraduate computer engineering course. Agglomerative hierarchical clustering, based on Ward's (1963) method, was used to detect five students' behavioural patterns (i.e., adopted learning strategies) based on the observed sequence of learning actions. This was followed by clustering students based on the identified behavioural pattern (i.e., learning strategies) for each of the four pre-learning activities over the course of the semester and how these impact on academic performance. The results revealed that there was an association between students' behavioural pattern, (i.e., adopted learning strategies) and their course performance. Students that adopted an intensive, strategic, or highly strategic approach to learning displayed higher levels of engagement with the pre-learning materials which lead to higher academic performance. Those that reduced their level of engagement and focused only on solving summative tasks resulted in lower academic performance. Thus, students' academic performance is influenced by the adopted learning strategy and their level of engagement with each of the pre-learning activities. These results, however, did not elicit reasons why students adopted a particular approach nor what design features may have encouraged or inhibited students' behavioural patterns.

A more recent study by Dooley and Makasis (2020) adopted a similar clustering analysis approach but only used three parameters to gain an understanding of students online learning behaviours with the pre-learning materials of a flipped pre-veterinary science course. It was noted that the parameter measuring the first time students accessed the pre-learning materials relative to the in-class session was a key indicator of students' performance. Students that accessed the pre-learning materials as originally intended (i.e., before the in-class session) received better course grades when compared to those that accessed the pre-learning materials after the in-class session. The other two parameters, the number of sessions and size of session, appeared to have no association with students' academic performance. In contrast, AlJarrah et al. (2018) found no significant difference in the time the pre-learning materials were accessed between low and high performing students. Although both studies reported the use of similar pre-learning materials (pre-learning videos and complementary learning activities) differences in results may be related to the instructional design of the flipped learning model and the relationship between the online pre-learning materials and the active in-class learning activities.

Brennan et al. (2019) provide a broader alternative approach to explore students' online behavioural patterns across a large diversity of courses (n = 225) range courses that are not limited to adopting a flipped or partially flipped learning model. Students' online behavioural patterns were based on the relative frequency of access of each of the four online activities: content views, discussion posts, content downloads and others. A total of 64 behaviours were identified that correspond to a unique behavioural pattern and were ranked in a descending order based on the aggregated frequency of weekly access in each of the four online activities. Despite the wide variation in behaviours, it was noted that students' behavioural pattern may not be limited to those 64 identified patterns, and the frequency of access does not reflect the level of engagement with the content presented. It was proposed that these variations in behavioural patterns may be attributed to individual preferences, the instructional design of the course and how instructors can encourage or inhibit certain behaviours. Changes in behavioural diversity were captured on a weekly basis over the length of a semester for a given course using two metrics: richness and evenness. Behavioural richness is the number of different behaviours observed within a course. This metric, however, is biased towards rare behaviours as it only considers the presence or absence of behaviours and is bounded between 1 to 64. Thus, low richness refers to rare behaviours and high richness refers to common behaviours. Behavioural evenness measures the frequency of these behaviours. This metric, however, is also biased towards common behaviours, as it only considers the frequency of each of the 64 behavioural types in each week. Thus, low evenness refers to one or few dominant behaviours, whereas high evenness refers to behaviours of similar frequencies. It was reported that behavioural richness decreased over the duration of the semester whereas behavioural evenness remained relatively constant but reflected some strong dominant behaviours with relatively equal distributions of students in each behavioural type. It was also observed that students tend to shift towards a common online behaviour which may be influenced by the structure of the course. The approach reported by Brennan et al. (2019) proposes a valuable tool to examine students online behavioural engagement and evaluate engagement level with a variety of online learning activities. Adopting this approach within a flipped or partially flipped learning context can potentially provide valuable insight regarding the varying behavioural patterns present within a course with reference to the specific pre-learning materials embedded. It can also highlight how students' initial behavioural patterns may change of the course of the semester and identify which behavioural pattern is the most dominant.

2.5.10 Impact of flipped learning on approaches to learning

Leiva-Brondo et al. (2020) examined life science students' approaches to learning using the R-SPQ-2F questionnaire across thirteen different courses to identify the factors that may have influenced their approaches. Students' deep approach scores were higher than their surface approach scores which suggested that a deep approach was their preferred approach to learning. Difference in a students' approach to learning were noted between subjects. This was mainly attributed to the different requirements associated within each discipline and the wide range of instructional course designs implemented instead of the level or year of the students.

Although the study by Leiva-Brondo et al. (2020) reports on students' approaches to learning across a wide range of instructional approach approaches, students' approaches to learning is still insufficiently explored in a partially or flipped learning model. Jeong et al. (2019) attempted to address this gap and explored students' self-identified approach to learning using the R-SPQ-2F questionnaire in a flipped undergraduate sustainable science course. When comparing R-SPQ-2F questionnaire responses pre- and post-course completion, students had a general inclination towards adopting a deep approach to learning; the number of students with a deep approach to learning score increased and those with surface approach to learning score decreased. Further analysis revealed that when comparing a students' deep and surface approach score difference to their academic performance, a positive correlation was observed which suggests that students with a deep approach to learning achieved better in the learning outcomes as they may have been more engaged in the learning process. These findings provide a general understanding about students' self-identified approaches to learning but remains limited in its scope as it was not clear which component of the flipped learning model prompted students to adopt their preferred approach. Hava (2021) proposed that students' approach to learning is highly influenced by the innovative teaching and learning activities embedded in the learning environment. The results from the R-SPQ-2F questionnaire revealed that the use of a flipped learning model in undergraduate courses was more effective than traditional teaching methods in promoting students' use of deep learning approaches. No differences, however, were noted in relation to surface learning approaches. Higher levels of cognitive and emotional engagement were also observed in the flipped learning format when compared to the traditional format, however, no differences were observed between students' behavioural engagement levels. It appears that the various components of the flipped learning model may have contributed to the observed differences. Results of a study by Danker (2015) align with these findings and further suggests that the pre-learning material provide students with a valuable opportunity to engage with the course content at a pace that suits their individual learning needs prior to the in-class sessions. The pre-learning material encourages students to be more cognitively engaged in building upon their knowledge through various interactive learning activities. A study by McLean et al. (2016) reinforces the need for further research to investigate the impact of flipped learning on students' approaches to learning. It was highlighted that the perceived benefits of the flipped learning model extend beyond academic gains. Students reported that they used deep and active learning strategies to engage with the pre-learning material and the interactive in-class component. However, these findings were based on students self-reported weekly responses; future qualitative research in the form of observational session, individual and focus group interviews can provide further insight regarding students' adopted approaches to learning.

The study by Hamm and Robertson (2015) complemented the use of R-SPQ-2F questionnaire with semi-structured interviews to gain a deeper understanding about students self-identified approach and their observed learning behaviour in a multimedia course. The results revealed that students can adopt either a surface, deep or strategic approach towards their learning which was mainly influenced by individual factors such as their motivation and course. Moreover, it was observed that students' self-identified approaches to learning from the R-SPQ-2F questionnaire does not necessarily align with their self-described learning behaviour. This highlights that there might be underlying factors that influencing students' approaches to learning and the need to examine these holistically through various quantitative and qualitative measures.

2.5.11 Impact of flipped learning on students' perception of learning

There is substantial research investigating students' perception of learning in a flipped or partially flipped learning model, with the majority reporting a generally more positive perception when compared to a traditional learning environment in undergraduate chemistry courses (Flynn, 2015; Seery, 2015). Similar trends were reported across several studies. Students perceived positively this instructional design due to the flexibility it offers in independently accessing online pre-learning materials at a pace that suits their learning needs, individualised and personalised learning opportunities and increased interaction with peers and teachers during the in-class session (Christiansen, 2014; Mooring, Mitchell, & Burrows, 2016; Roach, 2014; Shattuck, 2016). Others have reported mixed results. For example, He at al. (2016) observed that academically well-prepared students tend to perceive the learning environment more positively due to the variety of learning activities embedded across the various components of this instructional design. Those students that negatively perceived the learning environment often did not comply with completing the pre-learning material and was seen as “extra work” they had to complete instead of a shift in workload. A more recent study by Ponikwer and Patel (2018) revealed that students appreciated the pre-learning materials, specifically the ability to check and apply the knowledge they have attained from the pre-learning video in the interactive in-class activities. Students that had a negative perception towards learning in a flipped learning environment often commented on the level of difficulty of the concepts presented and the inability to seek clarification online which made learning during the in-class session hard to understand. Consistent with the results of He et al. (2016), students in this study found adjusting to this learning environment challenging as they had to adapt their approach and take ownership of their own learning.

Further research conducted in other undergraduate science courses focused specifically on examining students’ perception towards the pre-learning videos. Long et al. (2016) reinforce and extend some of the above-mentioned points related to the pre-learning videos. Generally, students perceived the pre-learning videos to not only to be easily accessible but also to be well-structured. They perceived them to be a valuable learning tool to build their conceptual understanding and aid them in completing the complementary pre-learning quizzes. Students preferred the pre-learning videos to be kept relatively short and to be developed by the course instructors. Similar findings were observed by Xiu et al. (2019) who showed that most of the students perceived the pre-learning videos to facilitate their learning, however, some reported the inability to promptly ask questions online hindered their learning experience whilst others noted that watching the pre-learning videos required more time and effort than other forms of tasks.

Chapter 3: Methodology

3.1 Ethical consideration

The research reported in this thesis involves human participants and was conducted in an ethical manner to protect the rights and welfare of the research participants. The research was designed in accordance with the guidelines outlined in the 2007 National Statement on Ethical Conduct in Human Research by the National Health and Medical Research Council (NHMRC). It is necessary to explicitly consider and comply with these guidelines throughout every stage of the investigation to address any foreseen or potential ethical concerns or issues (Denzin & Lincoln, 1994). In addition to the National Statement on Ethical Conduct in Human Research (2007), it is essential to obtain permission to conduct the research from the relevant Human Research Ethics Committee (HREC) at the University of Sydney. Two separate ethics applications were submitted. The projects were recognised as low risk and approval was granted for the research. Copies of the approval letters obtained from HREC for both projects are included in Appendix A. Project number 2014/219 referred to the investigation of students' online learning experience in junior and intermediate chemistry courses, focusing on their approach to learning and eliciting reasons for their interaction with the online learning resources (Appendix B). Project number 2016/190 referred to the investigation of the efficacy of flipped learning to promote student engagement and achievement in junior (first year) and intermediate (second year) chemistry courses (Appendix C).

The 2007 National statement on Ethical Conduct in Human Research by NHMRC outlines four main aspects that need to be considered with respects to ethics when research involves human participants. These, as well as other ethical principles from the literature (Kayser-Jones & Koenig, 1994), were carefully considered in the design and implementation stages of this research. The importance of these aspects will be discussed in the points below and in greater detail in the following sections:

- Research merit and integrity
- Respect:
    - Informed consent and voluntary participation
    - Privacy, anonymity, and confidentiality
- Beneficence: risk versus benefits
- Justice

3.1.1 Research merit and integrity

The research described here adheres to the requirements outlined by the National Statement on Ethical Conduct in Human Research (NHMRC, 2007). The research has merit as it is justified by potential benefits, its methods were designed to align with the aims, and it is based on a comprehensive review of the literature. The research was conducted by experienced and competent researchers in the field of chemistry education.

The perceived benefits of this project are twofold. One relates to its contribution to the body of research related to students' approaches to learning and interaction with the online learning component of a partially flipped learning model in junior and intermediate chemistry courses. The second is that the research findings may inform future design and development of online resources to support the wider student learning experience. The qualitative and quantitative research methods employed are commonly used in the chemistry education field, and appropriately align with the research aims and the research context. Research merit was maintained by the inclusion of experienced researchers in chemistry and tertiary education to supervise the project.

This research was conducted with integrity since it was committed to search for knowledge and understanding, while following principles of research such as honesty. Additionally, the results were, or will be, disseminated and communicated (NHMRC, 2007). Research findings have been published in the Journal of Chemical Education (JCE), presented at the conferences for International Scholarship of Teaching and Learning (ISSoTL), and the Junior Researchers (JURE) of European Association for Research on Learning and Instructions (EARLI) conferences. By communicating the research findings, contributing knowledge, and understanding to the field of flipped learning, the research was open for scrutiny, reinforcing the integrity of it.

3.1.2 Respect

3.1.2.1 Informed consent and voluntary participation

Participation in the questionnaires, interview, and observational session was voluntary. Learning analytics data were collected for all the enrolled students to examine their interaction patterns with the online pre-learning materials of the partially flipped learning model, but data were triangulated for only those that consented. During the recruitment process, the idea that participation was voluntary was reinforced and an emphasis was placed on this. Furthermore, it was clearly stated that a student's decision regarding participation would not have any effect with respect to their candidature or course grade.

To comply with the HREC conditions, students were provided with a Participation Information Sheet (PIS) outlining the context of the research, including the data collection methods (questionnaire, interview, observational session, and data tracking) and the implications of their participations in the study. Participants were informed that completion of a questionnaire was required as an indication of their consent to participate in the study. The use of students' tracking data from their LMS e-learning records is controlled by the University of Sydney's Privacy Policy (2017) and the consent the students give as part of their enrolment. The ethics application for the project number 2016/190 permitted the use of tracking data to address the aims of the research. Furthermore, students were informed that at any point prior to the de-identification of an individual's data, it was possible for them to withdraw.

Participants who were willing to take part in other stages of the research, for example in interviews and observations, were asked to provide their university email address on the consent form. Only these participants were contacted to arrange suitable meeting times. Informed consent was obtained to audio tape the interviews and video observations from these participants.

3.1.2.2 Privacy, anonymity, and confidentiality

The confidentiality of participants was maintained throughout the research process. Students were asked to provide their Student Identification Number (SID) to link student questionnaire, interview responses, observations, and data tracking with final course grades, so students were de-identified for this process, but it was not possible for it be conducted anonymously. To comply with the HREC conditions, the PIS informed students that their SIDs would be removed prior to dissemination of any results to ensure confidentiality. The participants' identity was further protected by ensuring that only the author was able to identify the participants. This information was not provided to any other individuals. Pseudonyms for interview participants were used as another means to ensure participants' privacy, confidentiality, and anonymity.

3.1.3 Beneficence: risk versus benefits

The principles of beneficence ('risk versus benefits') were considered in the design and conduct of this research. The HREC identified this study as low risk, as no potential harm was associated with students participating in the project. The data collected from the surveys and interviews were de-identified, which presents no risk of harm to the participants when research findings are disseminated. Students' course grades were not affected by their participation in the project. The only identified discomfort or inconvenience is related to students giving up their time to participate in completing surveys and interviews. Whilst the results obtained from these surveys and interviews will not directly benefit the current participants, future students may benefit from improvements made to the design and delivery of online learning resources in a partially flipped learning model to teaching chemistry courses.

3.1.4 Justice

This research complies with ethical principles of justice by managing the recruitment process in a manner that fairly considers the distribution, and the inclusion and exclusion of research participants (NHMRC, 2007). The recruitment of the participants was conducted fairly and followed procedural justice by informing all first and second year chemistry students of the research project during one of their weekly compulsory lectures. This ensured that all students were made aware of and had access to the same research information irrespective of their course level or stream. All students were eligible to be potential participants in the study as no exclusion criteria were used in the recruitment process.

Distributive justice is evident in the "fair distribution of the benefits and burdens of research" (NHMRC, 2007). No unfair burden resulted from participating in this study except for the inconvenience caused to students by time consumed in relation to data collection. The benefits from this study may not directly impact current participants but will potentially inform changes in courses that can benefit future students.

3.2 Quantitative and qualitative approaches in educational research

The design of educational research is classified under three major paradigms: qualitative, quantitative, or mixed methods approach (Cohen, Manion, & Morrison, 2007). These paradigmatic approaches differ with respect to their ontological and epistemological assumptions, methodology and research methods (Kuhn, 1970; Bryman, 2008). Ontology is related to the "claims and assumptions made about the nature of social reality" (Grix, 2004, p. 59). Whereas epistemology is related to a set of methods used in investigating and learning about social reality (Bryman, 2008). These underlying assumptions can inform which approach will be adopted by the researcher to investigate the phenomenon of interest. A quantitative approach is grounded in the philosophical ideas of positivism whereas a qualitative approach is mainly founded on the philosophical ideas of interpretivism (Hammersley, 2014).

A positivist approach perceives realities to be scientific and static in nature (Bryman, 2001). The use of quantifiable methods generates numerical data from predetermined variables to acquire knowledge about the investigated phenomenon (Creswell, 2009). This approach is deductive as it focuses on the theory and relies on hypothesis testing (Minichiello, 2004). The use of a quantitative approach can yield knowledge that is verified empirically and replicable. It also enables the researcher to objectively draw inferences from the findings, predict and generalise their data to a larger population sample. To achieve this, the research methods that can be employed are experiments and surveys. In these methods, the researcher is not directly in contact with the participants and as such, yield results that are free from bias.

An interpretivist approach perceives realities to be dynamic in nature and socially constructed (Johnson & Christensen, 2012). The use of qualitative methods generates non-numerical data and draws on multiple interpretations to gain factual and descriptive information about the investigated phenomenon (Johnson & Christensen, 2012). In this approach, knowledge is obtained by acknowledging "the differences between people and the objects of natural science and therefore requires the social scientist to grasp the subjective meaning of social action" (Bryman, 2001 as cited in Grix, 2004, p. 64). This reinforces the notion that data captured from multiple perspectives can provide a unique understanding about the complexity of the investigated phenomenon (Creswell, 2009). This approach is inductive as it focuses on developing "a theory or pattern of meanings" (Creswell, 2009, p. 9). The research methods that can be used include interviews, observations, tracking patterns and focus groups. In these methods, the researcher is drawing inferences from the participants personal experiences, behaviours, and interactions with the investigated phenomenon.

Quantitative and qualitative approaches are incompatible as each offers a distinct contribution to understanding the investigated phenomenon (Smith, 1983). Despite this, Bryman (2001) suggests that research should avoid this ontological and epistemological divide and instead adopt a mixed method approach. By combining both approaches greater insight can be obtained and stronger inferences can be made about the investigated phenomenon when compared to using findings from a single approach. A mixed method approach can overcome shortcomings related to validity and reliability of results obtained from using a single approach. A mixed method approach supports triangulation of research data, which promotes the credibility of inference drawn from both quantitative and qualitative approaches (discussed further in Section 3.3).

In this thesis, a quantitative dominant mixed methods approach was used to gain an understanding of students' learning experience with the online component of a partially flipped learning model (Johnson, Onwuegbuzie, & Turner, 2007). The two research methods were concurrently conducted to collect and analyse the data in parallel (Venkatesh, Brown, & Bala, 2013).

3.3 Triangulation of data

In educational research, triangulation involves the use of multiple methods of data collection or analytical approaches to examine the phenomena being studied (Cohen et al., 2007; Burns, 2000). There are various forms of triangulation. Methodological triangulation (Denzin, 1970) was used in this study to corroborate qualitative and quantitative data against one another to investigate students' online learning experience in a partially flipped learning model. This multiple-method approach (Denzin, 1970) can lead to gaining a comprehensive understanding of the "richness and complexity" (Cohen et al., 2007, p. 141) of the students' behaviours and interactions with the resources. This might not have been possible if a single method for data collection was used to examine the phenomenon as it is limited in its scope (Cohen et al., 2007).

Moreover, the use of methodological triangulation is perceived to be an effective approach as it enhances the internal validity of the data and leads to confirming the research findings obtained, as conclusions investigating the same phenomena are drawn from multiple data sources (Meijer, Verloop, & Beijaard, 2002).

In this thesis, various types of data were used to address the research questions (see Sections 3.3.1–3.3.4). The data are initially analysed independently and then triangulated to explore the research questions from various perspectives. This provides a holistic understanding of the research questions being explored.

In this study, data were collected from a range of sources:

- A survey instrument was used to gather demographic information, students' learning preference and perception of the online learning resources.
- Semi-structured interviews were conducted to gain a comprehensive understanding of their personal online learning experience.
- Tracking data were used to examine students' behaviour patterns and interactions with each of the online learning resources.
- Observations were used to gain an insight on how students interact with the online learning resources.
- Performance data were collected from the online component (weekly pre-learning quizzes), in-semester quizzes, end of semester examination and overall theory course performance.

3.3.1 Survey instruments

Surveys provide a quantitative description "on one or more characteristics of a specific population" (Gay, Mills, & Airasian, 2009, p. 175) and may "serve as a stimulus for more in-depth analytical research" (Brewers, 2009, p. 520). Survey data allow researchers "to gain insight into the thoughts, ideas, opinions, and attitudes of a population" (Brewers, 2009, p. 520). In addition, with larger cohorts surveys are a feasible research method to collect a representative data sample and therefore improve the statistical power of the analysis (Leppink, Winston, & O'Sullivan, 2016). Another perceived benefit of using surveys is the ability to use pre-established and validated instruments to measure the desired parameters of the research. While a researcher can construct a new survey instrument, the design of the parameters needs to be carefully considered so that they yield reliable result under similar conditions and are valid for measuring the intended research. The refining and validation processes can be time consuming. Another potential disadvantage associated with data collected by survey is that participants may not always provide an accurate representation of themselves and instead provide an idealistic view. This self-reporting bias should be considered when interpreting data.

For this thesis, two surveys were administered either during the laboratory sessions or online to collect a representative sample form the large cohorts of undergraduate chemistry students.

The first survey was administrated at the beginning of semester 1 (weeks 2-3) and consisted of two parts. The first part was used to gather general demographic participant information. The second part included Biggs et al.'s (2001) R-SPQ-2F questionnaire to identify students' metacognitive approaches to learning (See Appendix D). Further details regarding the use of this questionnaire are found in Section 6.2.2.1.

The second survey was administrated at the end of semester (weeks 12-13). The survey was internally developed by the research team to gather information about the students' perception towards their learning experience with the online pre-learning materials. The survey included a combination of closed-ended questions, 5-point Likert-type questions, and open-ended questions (See Appendix E). Further details regarding the use of this questionnaire are found in Section 5.2.2.3.

3.3.2 Tracking data

Learning analytics is widely used in the field of flipped learning as an alternative approach to quantify students' interaction with the online learning resources (Seery, 2015; Flynn, 2015). This approach provides a direct analysis of students' actual behaviour instead of relying on their self-reported behaviours (Jovanović et al., 2017). In this thesis, students' behavioural patterns were tracked through accessing their interactions with each of the online learning resources of the partially flipped learning model, which were captured by the University's LMS. The LMS click data were recoded via a bespoke software written by one of the members of the research team, which recorded students' weekly behaviours with the pre-learning videos and pre-learning quizzes over the course of a semester. The metrics measured for students' video-viewing behaviours were the frequency of views, and the time of access for each video. The time spent watching the video and whether students were actively watching it during that length of time were not recorded. These video-viewing metrics could have provided valuable information regarding whether the students watched them in part, fully or even repeated certain segments but the software used did not allow for such data collection. The tracking data for the pre-learning quizzes provided an in-depth view of students' behavioural patterns. From these data, it was possible to identify the frequency of access, time of access of each attempt, score for each attempt, how many questions were (in)completed for a given attempt, the time spent to select an answer and the time spent reading the provided feedback. The gathered tracking data were then exported as a csv file and imported into Excel to analyse students' weekly trends with the videos and associated quizzes. Section 4.3.1 provides further details on which metrics were used for developing an index that measures students' online engagement with the pre-learning videos and pre-learning quizzes.

3.3.3 Observational methods

Observational methods are used to collect data in a real-time setting and focus on understanding human behaviours and interactions as they unfold during the observed event (Cohen et al., 2007). In this approach, data are obtained from a natural setting and are less influenced by the researcher's personal agenda (Cotton, Stokes, & Cotton, 2010). However, this approach results in a vast range of unstructured data that might present practical challenges when transcribing it and might deviate from the focus of the investigated research question (Cotton et al., 2010). Agar (1980) suggested use of a progressive focusing approach or funnelling process (Cousin, 2009) whereby the researchers make an informed decision about selecting parts of the dataset to focus on that are directly related to addressing the investigated research question.

In this thesis, observational sessions were conducted by the researcher based on the participants availability during the semester in the University's learning centre at the School of Chemistry. Based on students' responses to the R-SPQ-2F questionnaire, a representative sample of students were selected to gain a more detailed insight into *how* students with varying self-identified approaches to learning interacted with the pre-learning materials. The data gathered from the R-SPQ-2F questionnaire responses, observational sessions and follow-up semi-structured interview were used in conjunction and presented in the form of case studies. Entwistle's (2000) characterisation features of surface, strategic, and deep were used to describe the adopted approach in each of the case studies. Section 6.2.2.3 describes in more details the observational sessions and case studies.

3.3.4 Interviews

The selection of interview types and techniques are often guided by which ones most appropriately address the research questions (Hobson & Townsend, 2010). Powney and Watts (1987) described interviews as "conversational encounters to a purpose" (p. vii). Semi-structured interviews allow greater flexibility in exploring the researchers' agenda whilst also providing interviewees with the opportunity to freely express themselves (Hobson, & Townsend, 2010). To effectively achieve this, Tomlinson (1989) suggested that semi-structured interviews should be conducted in a 'hierarchically focused manner.' That is, interviews are constructed based on an agenda and the researcher begins with a probing question that guides the interviewee to discuss their personal experience about the investigated topic. Throughout the semi-structured interview, a variety of techniques are employed to encourage interviewees "in a non-directive manner to elaborate and expand upon the views they are expressing" (Tomlinson, 1989, p. 169). The use of explicit prompts and targeted questions should only be used if the interviewee does not spontaneously target those areas of interest being investigated. The aim of this approach is to "elicit as spontaneous a coverage of as much of the interview agenda as possible" (Tomlinson, 1989, p. 169) to minimise the researcher's influence on the interviewees' responses.

In this thesis, semi-structured interviews were conducted by the researcher with participants that consented to the observational sessions, with no remuneration of their time, to elicit the reasons behind their adopted approach with the online pre-learning materials of the partially flipped learning model. The semi-structured interview questions build on those widely used to explore students' approaches towards learning (Bliuc, Ellis, Goodyear, & Piggott, 2010; Hamm & Robertson, 2010) but with a narrower focus on students' interaction with the online pre-learning materials (Appendix E). The interviews were designed to be approximately 20 minutes in length, audio recorded and transcribed by the researcher so responses can be analysed by thematic analysis. Section 6.2.2.4 describes in more details the semi-structured interviews and Section 3.6.1 describes in more details the process of thematic analysis.

3.4 Quantitative data analysis

3.4.1 Statistical hypothesis testing

In a research study, selection of appropriate statistical testing depends on the following three criteria (Mishra, Pandey, Singh, Keshri, & Sabaretnam, 2019; Parab & Bhalerao, 2010):

1. Number of variables: single variable often referred to as descriptive statistics or two/three variables often refers to as multivariable relationships.
2. Type and distribution of data used: parametric (continuous data) and non-parametric (nominal, ordinal, and discrete data).
3. Paired or unpaired observation: paired (same subjects are measured at different intervals or using different methods) and non-paired (different subject in each group)

In statistical hypothesis testing, a null hypothesis (H_0) and alternative hypothesis (H_A) are used to determine if the relationship between two or more variables is significant. The null hypothesis suggests no differences between variables, while the alternative hypothesis suggests that there are differences between variables. Hypothesis testing calculates statistical significance, or a *p-value,* which represents the probability that a result occurred due to chance alone (Sullivan & Feinn, 2012). When statistical tests are performed there are three threshold values 0.05, 0.01, and 0.001 that can be used to determine statistical significance (α). If the obtained *p-value* is less than the value of the selected threshold value of significance ($p < \alpha$), the relationship between the two or more variables is said to be statistically significant. Thus, we reject the null hypothesis and accept the alternative hypothesis.

The statistical tests reported on in this thesis compares the *p-value* against all three threshold values of significance. Several statistical tests were performed using Statistical Package for Social Science (SPSS) 26.0 for Mac.

3.4.1.1 Independent (unpaired) sample *t*-test

The independent samples *t*-test (unpaired sample *t*-test) is used to determine a significant difference in the mean score between two independent groups.

The independent *t*-test assumptions are:

1. Independence: two independent (categorical) groups are needed to represent an independent variable. No relationship between the observations in each group.
2. Normality: data for each group should be (approximately) normally distributed. The Shapiro-Wilk test of normality was used instead of Kolmogorov-Smirnov as it is more appropriate for sample sizes smaller than 2000 (Zimmerman, 2004).
3. Homogeneity of variance: the variance of the dependent variable should be equal at each level of the independent variable. To check for homogeneity of variance Levene's test for equal variance (*F*-test) is used. For unequal variance Weltch (*t*-test) is used.

3.4.1.2 One-way Analysis of Variance (ANOVA)

A one-way ANOVA is used to determine a significant difference in the mean scores between multiple independent groups. If a statistically significant result ($p < 0.05$) is obtained the H_0 is rejected. This suggests that there are at least two independent group means that are statistically significantly different from one another. A post-hoc test, Tukey's Honestly Significant Difference (HSD) can be used to determine which specific independent groups differed from one another.

3.4.1.3 Correlation analysis

Prior to conducting correlation analysis, a scatterplot is used to display the strength, direction, and form of the relationship between two variables.

Pearson's correlation (*r*) is a parametric test used to examine the linear relationship between two continuous variables (Ratner, 2009). In a linear relationship, a change in one variable is directly proportional to the change in the other variable. The correlation coefficient ranges between the values $-1 \leq r \leq 1$ and varies in the strength (weak, moderate, or strong) and direction (positive or negative) of the relationship between two continuous variables (see Table 3.1). No linear relationship is observed between the two variables when $r = 0$. A perfect positive linear relationship between variables is observed when $r = 1$ and a perfect negative linear relationship is observed when $r = -1$. The remaining accepted guidelines for interpreting the correlation coefficient are presented in Table 3.1

Spearman's correlation (ρ) is a non-parametric test used to examine the monotonic relationship between two continuous or ordinal variables. In a monotonic relationship, the variables change at the same time but not necessarily at a constant rate. The correlation coefficient is measured using ranked values for each variable.

Table 3.1. Suggested guidelines for interpreting the correlation coefficient.

	Direction	
Strength	Positive	Negative
Weak	0 to 0.3	0 to -0.3
Moderate	0.3 to 0.7	- 0.3 to - 0.7
Strong	0.7 to 1	- 0.7 to -1

3.4.1.4 Effect size

Cohen's effect size (*d*) complements statistical hypothesis testing as it measures the strength of the relationship between two variables (Sullivan & Feinn, 2012). It measures the differences in means between groups in terms of standard deviation and classifies effect sizes as small ($d = 0.2$), medium ($d = 0.5$) and large ($d \geq 0.8$). The use of effect size complements findings obtained from statistical significance test. A statistically significant difference between mean values of two groups does not necessarily indicate if the difference is substantial. For example, in a large sample size a statistical significance can be reached with a small effect size, in this case the results may not be of value, compared with a small sample size where statistical significance may not be observed although the effect size might be large.

3.5 Qualitative data analysis

3.5.1 Thematic analysis

Thematic analysis is used to identify patterns or themes derived from qualitative data, gathered in this thesis from open-ended questionnaire items, semi-structured interviews, and observational cases. By carrying out thematic analysis it is possible to interpret and make meaningful inferences of the research findings. There are two types of thematic analysis: semantic and latent. Semantic analysis focuses on "the explicit or surface meanings of the data and the analyst is not looking for anything beyond what a participant has said or what has been written" (Braun & Clarke, 2006, p. 84). In this case, data are analysed on a descriptive level. Whereas latent analysis focuses on identifying or examining "the underlying ideas, assumptions, and conceptualisations, and ideologies, that are theorised as shaping or informing the data" (Braun & Clarke, 2006, p. 84). In this case, data are analysed on an interpretive level to gain a deeper level of understanding of the participants responses. The distinction between these two types is important to consider when interpreting data as combined it provides a comprehensive understanding of the research findings.

3.6 Validity and reliability

In educational research, validity and reliability are two fundamental prerequisites used to ensure the merit and integrity of the data collection tools or instruments (Cohen et al., 2007; Creswell, 2009; Drost, 2011). By assessing validity and reliability it is possible to increase transparency and decrease potential bias of the research findings. This also enables researchers to effectively examine the relationship between two or more variables.

3.6.1 Validity

Validity has different forms depending on the nature of the educational research. In quantitative research, validity measures the accuracy to which a data collection tool or instrument measures what it is designed to measure (Cohen et al., 2007; Creswell, 2009; Drost, 2011). The validity of quantitative data can be improved by using appropriate sampling methods, suitable tools or instruments, and appropriate statistical analysis tests to examine the data (Cohen et al., 2007). Since it is difficult to reach optimum validity (i.e., 100%), it is important to acknowledge the standard error which is typical built into quantitative research methods (Cohen et al., 2007). In contrast, validity in qualitative research relies on the researcher to follow certain procedures to confirm the accuracy of the research findings (Creswell, 2009). The validity of qualitative data can be improved by extending the scope of the data, the methods in which participants are approached, the use of triangulation and the researcher's objective stance in analysing and interpreting the research findings (Cohen et al., 2007). By taking these into consideration it is possible to address any potential degree of bias gathered from the participants' subjective responses in relation to their opinion, attitudes, and perceptions (Cohen et al., 2009). As such validity "should be seen as a matter of degree rather than as an absolute state" (Gronlund, 1981 as cited in Cohen et al., 2007, p. 133).

There are two main parts for validity: internal and external validity. Internal validity focuses on whether the research findings are credible due to the way the participants may have been selected, and the way data were collected and analysed. Internal validity also focuses on the extent to which the examined cause and effect relationship is not influenced by other factors. As such it enables the researcher to determine whether the independent variable caused the observed change(s) in the dependent variable and if any confounding variable may have influenced the independent variable. External validity focuses on whether the research findings are transferable, in this case the extent to which the research findings can be "generalised to the wider population, cases or situations" (Cohen et al., 2007, p. 136). To increase external validity, it is essential to have a representative sample of the studied population so that inferences can be drawn from the examined sample and potentially extrapolated to the wider population.

In educational research, internal and external validity can be achieved by designing an experiment (i.e., a research study) in a suitable environment. In a true experiment, all the factors that may affect the observed variable are completely controlled. However, it is not often possible or practical to control all factors. Instead, a quasi-experimental research design may be used to investigate the relationship between variables. A true experiment controls the environment in which the research takes place and often does not reflect a natural setting compared to a quasi-experiment. Thus, although a quasi-experiment provides some control over certain variables it allows generalisation of research findings to be extended to broader contexts.

In this thesis, a quasi-experimental research design was adopted to measure the relationship between variables. To collect data, quantitative and qualitative research methods were used to enhance the internal and external validity of the research findings (Cohen et al., 2007, p. 156):

- Experimental mortality: participants systematically drop out over the course of the semester. For example, the number of students completing the online pre-learning materials of the partially flipped learning model may start with a high number of students, but that number may decrease over the course of the semester.
- Selection bias: the students self-select to participate so may not be representative. Participation was voluntary, while inferences can be drawn from the students that participated it was not feasible to draw conclusions about the remaining students. It was perceived that those who participated were somewhat engaged in the learning process.
- Sample size: small sample size may undermine the causal effect between variables, whereas a high sample size may observe small differences to be statistically significant.
- Hawthorne effect (reactive effect of testing): participant responsiveness to the measured variable. During the observational sessions if students were made aware of the investigated parameters, they may have altered their behaviour to achieve the researcher desired goal.

3.6.2 Reliability

Reliability has different forms depending on the nature of the educational research. In quantitative research, reliability measures the "dependability, consistency and replicability over time, over instruments and over groups of respondents" (Cohen et al., 2007, p. 146) of the research findings. In quantitative research, there is an assumption that the same research findings would be obtained if the research is replicated on a similar group of participants in a similar context. Unlike validity, reliability can be measured statistically using reliability coefficient to examine the correlation between two or more variables. Stability is another important concept which suggests that the measure will yield the same result and remain the same despite different research settings and respondents.

In contrast, reliability in qualitative research relies on the researcher's ability to record data of what takes place during the research setting (Cohen et al., 2007). In qualitative research there is no uniform approach to analyse the research finding and the level of reliability may be influenced by the researcher's subjective approach. Thus, two researchers can examine the same variables which may result in different interpretations, but both are reliable.

3.6.3 Relationship between validity and reliability

In educational research, it is essential for data collection tools or instruments to address the criteria for both validity and reliability (Cohen et al., 2007; Creswell, 2009; Drost, 2011). If a measure is valid but not reliable, it is measuring the intended variable from the selected instrument but not in a consistent way. Likewise, if a measure is reliable but not valid, it is measuring the consistency of the intended variable but using an inappropriate instrument. Therefore, it is essential to ensure both validity and reliability are met so that the data collected from the tools or instruments used effectively measure the aims of the research.

3.6.4 Validity and reliability of instruments used in this thesis

The validity and reliability of the various data collection instruments used in this thesis were considered. Biggs et al. (2001) R-SPQ-2F questionnaire was used to identify students' metacognitive approaches to learning. By selecting a widely recognised questionnaire it ensures that it has validated across various research contexts. The second questionnaire used focused on measuring students' perception towards their learning experience with the online pre-learning materials. The questionnaire items were internally developed by the research team and content validity was checked by an external researcher in the School of Chemistry. Both questionnaires were repeated to ensure consistent results (reliability) are obtained to address the intended research questions.

The observational sessions were used to explore students' approaches to learning with the online pre-learning materials. To achieve internal and external validity, a representative sample of students were selected to determine *how* students' individual approaches to learning attributed to variations in their interactions with the online pre-learning materials. While observational sessions provided direct evidence of students' behaviours in their natural setting (Carlson & Morrison, 2009), there is a high risk of observer bias. Two considerations were taken to address this, (1) conclusions regarding students' observed approaches to learning were made with reference to Entwistle (2000) learners characteristics of surface, strategic and deep learning and (2) follow-up semi-structured interviews to corroborate observational findings.

The questions used for the semi-structured interviews were adopted from the existing research on students' approaches to learning (Bliuc et al., 2010; Hamm & Robertson, 2010) with a more specific focus on their interaction with the online pre-learning materials.

The use of learning analytics provides extensive quantitative data (Joksimović, Kovanović, & Dawson, 2019), as it captures in real-time students' interactions with the online pre-learning materials. The internal validity was considered in the selection of the various metrics used to measure students' interactions with each of the pre-learning videos and pre-learning quizzes. Section 3.3.2 describes in more details the list of the metrics measured for each of the pre-learning materials. Furthermore, the external validity was met since tracking data was collected on a weekly basis for the same metrics over the course of a semester. Several data trends emerged, and inferences were drawn to generalise the findings to a wider context. To ensure the reliability of the tracking data several aspects were considered such as: the same bespoke software was used to extract the data, the same weekly pre-learning materials were used across the various chemistry groups and the same metrics were used to extract data regarding their interactions with each of the pre-learning videos and pre-learning quizzes.

3.7 Chemistry courses reported on in this thesis

The data reported on in this thesis were gathered from two groups of undergraduate chemistry students. Group A consisted of one cohort of first year undergraduate students. Data was gathered over one academic year (2017) for the semester 1 junior chemistry courses, at the fundamental, mainstream, and advanced level. The overall participation rate in each junior chemistry course for Group A is provided in Chapter 6.

Group B consisted of two cohort of second year undergraduate students. Data were gathered over two academic years (2016-2017), in a two-semester sequence, at the mainstream, advanced and special studies program (SSP) level. Group B_1 consisted of students enrolled in 2016 and Group B_2 consisted of students enrolled in 2017. The overall participation rate in each intermediate chemistry course for Group B_1 and Group B_2 during each semester is provided in Chapter 4 and 5. In addition, the total number of students that completed both semester 1 and semester 2 chemistry courses is provided in Chapter 4 and 5. See Sections 3.8 and 3.9 for full description for each of the chemistry courses.

The participants from Group A were unique as it was not possible for these participants to be enrolled in either Group B_1 or Group B_2. When comparing the participants of Group B_1 and Group B_2, 8 students were common across both groups for semester 1, whereas 4 students were common across both groups for semester 2.

At the University of Sydney, each semester consists of thirteen teaching weeks, one-week mid-semester break, one-week study vacation and two weeks of examination. For the junior chemistry courses, each teaching week consists of three one-hour in-class sessions and one one-hour tutorial session. In addition, there are nine three-hour laboratory sessions across the semester. For the intermediate mainstream and advanced courses, each teaching week consists of three one-hour in-class sessions. There are seven one-hour tutorial sessions and eight four-hour laboratory sessions across the semester. The intermediate SSP courses consist of three one-hour in-class sessions each week and twelve one-hour SSP seminars plus eight four-hour laboratory sessions across the semester.

3.8 First year (junior) chemistry courses at the University of Sydney

At the University of Sydney, junior chemistry courses are taken by a large cohort of first year students across a range of degree programs. Students enrol in these courses to major in chemistry, to meet their degree program requirements or out of interest. Prior to curriculum changes in 2018, the School of Chemistry offered five different two semester-sequence course streams in each academic year (see Table 3.2), with approximately 2,000 students completing a chemistry course in semester 1 (March-June). Of these, approximately 1,400 students commence or continue to complete a chemistry course in semester 2 (August-November). The concepts covered in semester 1 primarily focus on general and inorganic chemistry, whereas the concepts in semester 2 are divided between general, inorganic, and organic chemistry. Out of the five first year junior chemistry courses offered by the University, this thesis reports on data gathered for the following three first year junior chemistry 1A courses: Fundamentals of Chemistry (CHEM1001), Mainstream Chemistry (CHEM1101) and Advanced Chemistry (CHEM1901). The remaining junior courses will not be discussed further as they were not part of this study.

These three first year junior courses have broadly similar learning outcomes but differ in the depth of conceptual detail addressed, with enrolment generally based on advice on whether the student completed chemistry for their High School Certificate (HSC), and their performance score in the Australian Tertiary Admission Rank (ATAR) or equivalents. The HSC is the credential awarded in New South Wales, Australia to secondary high school students who have satisfactorily completed their senior level of studies (Year 11 and 12) (National Educational Standards Authority, 2018). The ATAR is a measure that ranks an individual student's position relative to the entire state-wide student cohort based on their HSC performance and ranges from 0 to 99.95. The ATAR is the primary criterion used by Australian universities for undergraduate student admissions.

Table 3.2. Junior chemistry courses at University of Sydney.

Unit title	Code	High school chemistry background knowledge	Semester offered
Fundamentals of Chemistry 1A*	CHEM1001	No prior	1
Fundamentals of Chemistry 1B	CHEM1002		2
Chemistry 1A*	CHEM1101	Sound	1 and 2
Chemistry 1B	CHEM1102		1 and 2
Chemistry 1A (Pharmacy)	CHEM1611	Sound	1
Chemistry 1B (Pharmacy)	CHEM1612		2
Chemistry 1A (Advanced)*	CHEM1901	Exceptional	1
Chemistry 1B (Advanced)	CHEM1902		2
Chemistry 1A (Special Studies Program - SSP)	CHEM1903	Exceptional	1
Chemistry 1B (Special Studies Program - SSP)	CHEM1904		2

*Junior chemistry courses investigated for this thesis.

3.8.1 Junior fundamentals of chemistry courses

The fundamentals of chemistry (CHEM1001 and CHEM1002) courses are designed for students who have not completed HSC chemistry or have a weak background in chemistry. Although no formal prior knowledge of chemistry is assumed, students are strongly advised to complete a chemistry bridging course offered prior to the start of the semester. The bridging course aims to familiarise students with the language of chemistry and provide fundamental theoretical knowledge and practical skills required for broad application in chemistry

(Bridgeman & George, 2014) generally equivalent to those in the core part of the HSC. Compared to the mainstream and advanced chemistry courses described below, the theory component of the fundamentals of chemistry course begins with more introductory concepts, and either does not include some topics, or covers the topics in less detail.

3.8.2 Junior mainstream courses

The mainstream chemistry (CHEM1101 and CHEM1102) courses are designed for students who have completed HSC chemistry. This course builds on students' prior knowledge and further develops this knowledge and skills in chemistry for application to a variety of fields and further study in chemistry.

3.8.3 Junior advanced courses

The advanced chemistry (CHEM1901 and CHEM1902) courses are designed for students who have received a mark greater than 80% in HSC chemistry and achieved at least 95% in their ATAR. Compared to the mainstream chemistry courses, the theory component of the advanced chemistry courses provides students with a "higher level of academic rigour and makes broader connections between topics" in chemistry (Unit of Study Outline, School of Chemistry, 2021).

3.9 Second year (intermediate) chemistry courses at the University of Sydney

To major in chemistry, students must successfully complete two junior level courses, two core intermediate level courses followed by four senior courses. Prior to the introduction of a new curriculum in 2019, three different two-semester courses were offered in each academic year. The courses in which a student enrols depends on which junior chemistry courses they have completed and their academic performance in those courses (see Table 3.3). Approximately 280 students complete Molecular Reactivity and Spectroscopy (CHEM2401, CHEM2911 and CHEM2915) in semester 1 (March-June) and of those students, approximately 200 continue to complete Chemical Structure and Stability (CHEM2402, CHEM2912 and CHEM2916) in semester 2 (August-November). The semester 1 courses focus on organic chemistry, medicinal chemistry, quantum theory and molecular spectroscopy. The semester 2 courses focus on coordination chemistry, predicting reactivity, materials, and nanotechnology. Students who complete these two core chemistry courses may also enrol in the elective courses in Forensic and Environmental Chemistry (CHEM2404), and the Chemistry of Biological Molecules (CHEM2403).

This thesis reports on data gathered for the following three core intermediate chemistry course, in a two-semester sequence. The first semester intermediate courses were: Mainstream Molecular Reactivity and Spectroscopy (CHEM2401), Advanced Molecular Reactivity and Spectroscopy (CHEM2911) and Special Studies Program Molecular Reactivity and Spectroscopy (CHEM2915). The second semester intermediate courses were: Mainstream Chemical Structure and Stability (CHEM2402), Advanced Chemical Structure and Stability (CHEM2912) and Special Studies Program Chemical Structure and Stability (CHEM2916).

Table 3.3. Intermediate chemistry courses at the University of Sydney. The pre-requisites are described in Table 3.2.

Unit title	Code	Pre-requisites	Semester offered
Molecular Reactivity and Spectroscopy*	CHEM2401	CHEM1101 and CHEM1102	1
Chemical Structure and Stability*	CHEM2402		2
Molecular Reactivity and Spectroscopy (Advanced)	CHEM2911	A mark of 65 or above in CHEM1101 and CHEM1102, or CHEM1901 and CHEM1902	1
Chemical Structure and Stability (Advanced)*	CHEM2912		2
Molecular Reactivity and Spectroscopy SSP*	CHEM2915	A mark of 75 or above in CHEM1101 and CHEM1102, or CHEM1901 and CHEM1902	1
Chemical Structure and Stability SSP*	CHEM2916		2
Forensic and Environmental Chemistry	CHEM2404	CHEM1101 and CHEM1102, or CHEM1901 and CHEM1902	1
Chemistry of Biological Molecules	CHEM2403		2

* Intermediate chemistry courses investigated for this thesis.

3.9.1 Intermediate mainstream courses

The mainstream chemistry (CHEM2401 and CHEM2402) courses are designed for students who have completed CHEM1101 and CHEM1102 in first year. Students who had completed the junior fundamentals courses needed to complete an online supplementary course before enrolling in intermediate chemistry courses.

3.9.2 Intermediate advanced courses

The advanced chemistry (CHEM2911 and CHEM2912) courses are limited to students who have either received a mark of 65 or above in the two mainstream junior courses or have completed both advanced junior courses. The theory component in the advanced courses is the same as the mainstream courses; the practical component, however, differs between the advanced and mainstream courses.

3.9.3 Intermediate special studies program (SSP)

The SSP chemistry (CHEM2915 and CHEM2916) courses are limited to students who have achieved a mark of 75 or above in the two mainstream junior courses or have completed both advanced junior courses. In these courses, the theory component is the same as the mainstream course and the practical component is the same as the advanced course. These courses, however, include an additional SSP seminar series on research led topics in chemistry.

3.10 Assessment and grading system

The course assessments and weighting for the junior and intermediate chemistry courses are represented in Table 3.4. At the end of the semester, the student obtains a final mark (out of 100) and a merit grade to reflect their performance in that course. Table 3.5 explains how the University merit grade descriptors relate to course marks.

Table 3.4. Assessment weighting (%) for junior and intermediate chemistry courses investigated.

Assessment format	CHEM1001, CHEM1002, CHEM1101, CHEM1102, CHEM1901, CHEM1902,	CHEM2401, CHEM2402, CHEM2911, CHEM2912,	CHEM2915, CHEM2916
Summative online pre-learning quiz	10	10	Not graded
In-semester tutorial quiz 1	5	7.5	3.75
In-semester tutorial quiz 2	5	7.5	3.75
In-semester tutorial quiz 3	5	-	-
Laboratory component	15	15	25
SSP Task 1	-	-	7.5
SSP Task 2	-	-	7.5
End of semester examination	60	60	52.5

Note. For all three junior course levels the online pre-learning quizzes are summative assessment. For the normal and advanced intermediate chemistry courses, the online pre-learning quizzes are summative assessment. For the SSP intermediate chemistry course, the online pre-learning materials are not compulsory, and no marks are rewarded for completion of the online pre-learning quizzes.

Table 3.5. Merit grade definitions at University of Sydney.

Merit Grade	Grade Code	Mark Range (%)
High Distinction	HD	85-100
Distinction	DI	75-84
Credit	CR	65-74
Pass	PS	50-64
Fail	FA	0-49

3.11 Design of the partially flipped learning model

The partially flipped learning model reported on in this thesis (Figure 3.1) is comprised of two major components, the online learning platform and the in-class learning sessions (Bokosmaty, Bridgeman, & Muir, 2019). While the online learning platform is comprised of four pre-learning elements, this thesis reports on student use of two of these resources: weekly introductory videos and the associated quizzes. Based on the course coordinator's experience with the content aspects of the course were flipped by identifying which learning outcomes would be most effectively delivered in the online learning platform and during the in-class sessions. Key chemistry concepts that require a developmental learning approach (e.g., moles, nomenclature, orbitals, etc.) and have been traditionally delivered during the in-class sessions of the course were shifted to the online learning platform. The intention was to free up time for the in-class session so that students can engage in a series of active learning opportunities facilitated by the teaching team (Section 3.11.2.2 provides an example of this). The pre-learning materials were designed to expose and develop students' foundational knowledge and understanding of key chemistry concepts prior to the in-class learning sessions.

Over the course of a semester students were expected to interact with the 10 weekly online pre-learning materials by watching the assigned pre-learning video that provides an overview of the foundational key concepts explored across the three weekly in-class sessions, followed by completing the associated pre-learning quiz to master the material, and use the embedded formative feedback to address any misconceptions. The pre-learning materials were purposefully designed to balance between the students who complete them whilst not marginalising those who do not. For instance, the design of the pre-learning quiz questions was targeting lower cognitive processing skills to measure students' mastery of the key concepts presented during the pre-learning videos. The other pre-learning materials were optional, and participation was voluntary. The web-based tutorials provided further support to the concepts addressed in the videos and quizzes. A discussion forum allowed students to seek further clarification related to the weekly concepts presented.

Content delivered in the in-class sessions was not entirely didactic; but rather combines 50% instructor-led and 50% independent or collaborative interactive learning activities focused on inquiry to facilitate a student-centred learning environment. These in-class sessions are delivered by one instructor in a fixed seating, tiered, theatre-style auditorium with a capacity for approximately 300 students. Typically, students are expected to attend three weekly in-class sessions that are streamed live two or three times depending on the chemistry course. The flexible nature of the in-class component enables the instructor to deliver parts of the course content that are perceived to be challenging whilst simultaneously devoting the remaining class time to active learning. Moreover, the instructor can adjust the number of active learning activities and the time spent on them whilst providing students with feedback at various intervals throughout the in-class session.

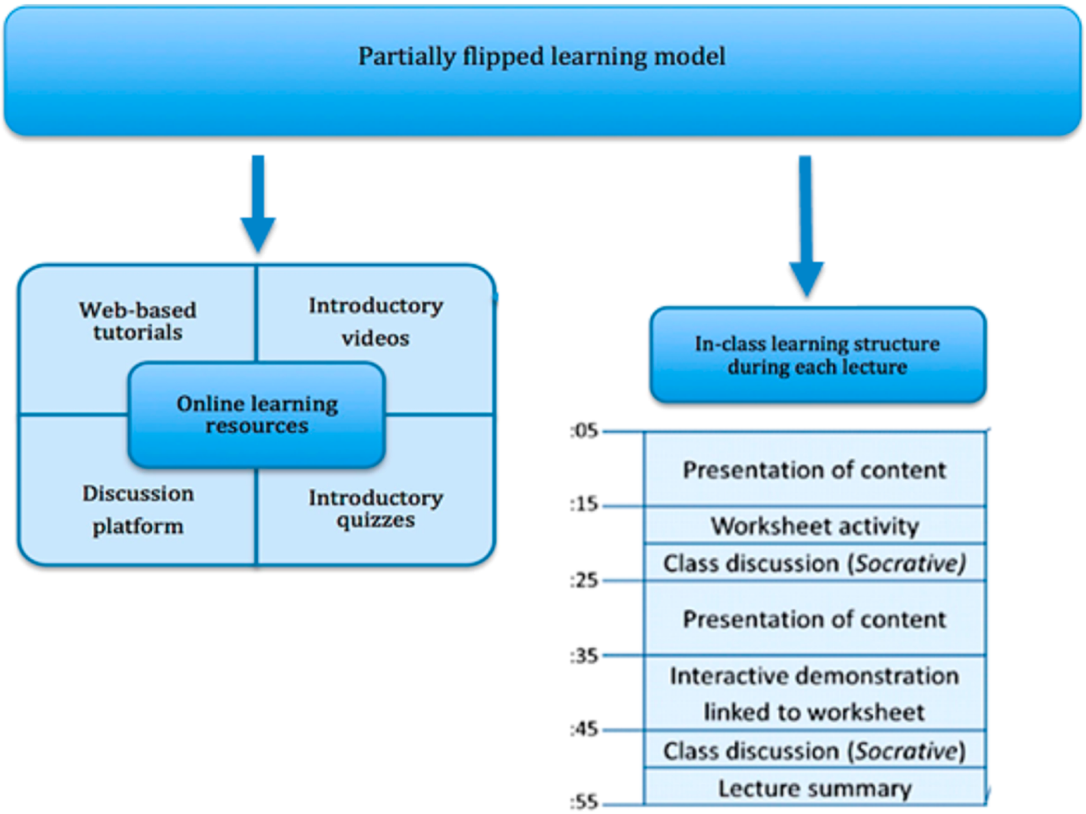

Figure 3.1. Overview of the partially flipped design implemented in the junior and intermediate chemistry courses. The pre-learning material is delivered in the online learning platform. In-class learning activities are delivered in segments of varying length, suggested timing in minutes (extracted from Bokosmaty et al., 2019, p. 630).

3.11.1 Active in-class learning component of the partially flipped learning model

The in-class sessions were structured in a series of segments. During each in-class session, the instructor initially recaps key concepts from the previous lesson followed by a series of short segments involving instructor-led content delivery, peer collaboration on the inquiry-based worksheet, chemical demonstrations and classroom discussion mediated by Socrative: an interactive web-based student response system (https://www.socrative.com).

Inquiry-based worksheets, adapted in style from the widely used instructional initiative Process Oriented Guided Inquiry Learning (POGIL) (Moog & Spencer, 2008), were used to facilitate a student-centered learning approach during the in-class sessions. The POGIL worksheets are designed as a single two-sided sheet with a brief description of the theory followed by a series of questions "broken down into two or three self-contained blocks" (Bokosmaty et al., 2019,

p. 632). They were provided as a hard copy at the start of each in-class session and can be accessed online post-class through the LMS.

The POGIL-style worksheets supplemented the segments of the instructor-led explanation delivered during the in-class sessions with the intention to actively engage the students in the learning process and encourage peer-to-peer collaboration. Two types of worksheets are used depending on the chemistry concept delivered; either a worksheet that is primarily theory based or one that focuses on integrating interactive lecture demonstrations.

Formative clicker questions using Socrative were embedded in various segments of the in-class sessions to provide instructors and students with real time feedback about their progress. They were also used to check students' understanding, extend certain sections of the POGIL-style worksheet or poll students for their opinion on some topics.

In each of these cases, the students' responses allow the instructors to identify the potential misconceptions and misunderstandings. These also create and promote a social learning environment where students can work collaboratively and individually to assess their knowledge.

3.11.2 Interactive online learning component of the partially flipped learning model

The primary platform by which students access course materials is the University's LMS (Blackboard during this research). An interactive e-learning site was developed on an external server and embedded in the LMS (Bridgeman, 2011). This was only available, however, for junior chemistry courses. A "crowd sourcing" approach, like the one used on news aggregation sites, was used to extend the resources for each topic. Each resource is automatically tagged under the relevant topic with a brief description (Figure 3.2). These supplementary resources can be added by any member from the teaching team and/or student enrolled in the course. The list of resources is then ranked according to votes based on how "useful" or "useless" each resource was perceived by members of the teaching team and students. The votes made by the teaching team weigh higher than those of students.

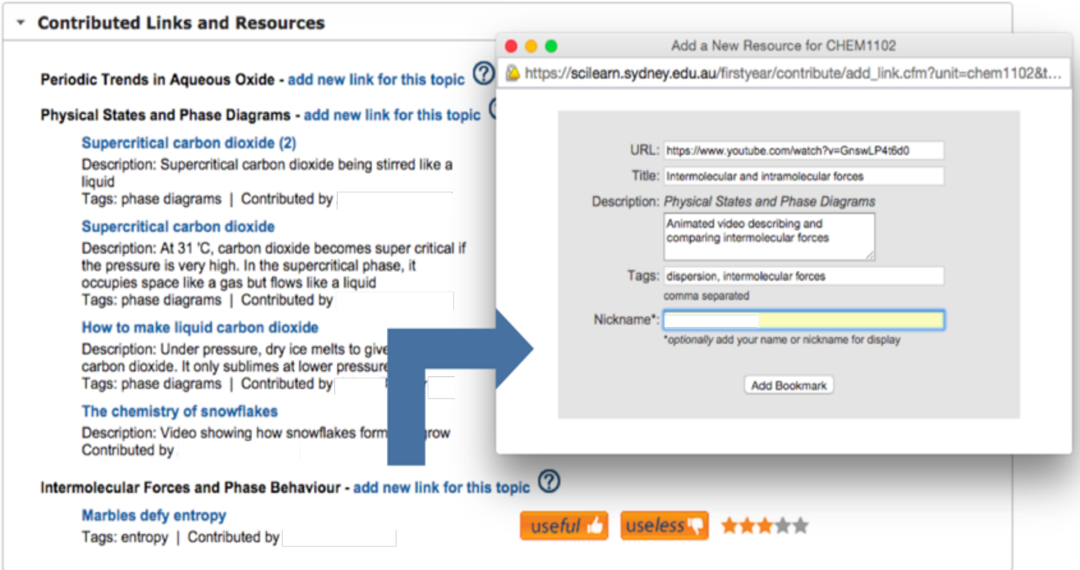

Figure 3.2. Example of the crowd sourcing approach used in junior chemistry courses for contributing links and resources (extracted from Bokosmaty et al., 2019, p. 631).

3.11.2.1 Pre-learning videos

Several principles from Mayer (2005) cognitive theory of multimedia learning were considered to effectively design the pre-learning videos and support students' learning experience. The *multimedia principle* suggests that people learn better from words and pictures than just words alone. The *voice principle* states that people learn more effectively from a human voice rather than an automated computer voice. There was no standard video composition format followed instead the format varied depending on the weekly concepts addressed with some pre-learning videos focusing on content delivery whereas others were problem-solving based. Tables 3.6 and Table 3.7 lists the weekly videos for the junior and intermediate chemistry courses respectively, the video tittle reflect the key concept of that week. The weekly videos using screencasts, capturing audio narration supplemented with visual support were developed by various members of the chemistry teaching team using PowerPoint. The pre-learning videos were then published as multimedia resources hosted and delivered through YouTube channels (Adam Bridgeman and Sydney 2nd year YouTube channel), accessed by an external link embedded in the LMS. The screencast materials were chunked to produce short segments (5-10 minutes) to ensure that the students' attention span did not decline. Additionally, the length of the videos was kept relatively short to take into consideration the students' workload and avoid an overwhelming amount of learning expected to be completed prior to the in-class component. This aligns with the *segmenting principle*, which suggests that people learn more effectively in segments rather than one continuous stream, as it gives them the flexibility to self-direct their learning as they access the videos and progress at a pace that suits their learning (O'Flaherty & Philips, 2015).

The design of the pre-learning videos also adhered to the *coherence principle* which suggest that people learn best when extraneous materials are excluded and the *redundancy principle* which focuses on the use of narrations and visual support, instead of narrations, visual support, and text. For example, during the video on assigning the absolute configuration of a stereocenter as (R) or (S), extraneous materials are excluded, the video begins by presenting a simple visual diagram of the molecule. The audio narration coherently works through the various steps required to assign the configuration of the molecule (as seen in the following link: https://www.youtube.com/watch?v=5Zg9FYKFAlQ).

Table 3.6. Weekly pre-learning materials video topics for junior chemistry courses across both semesters.

Pre-learning material	Week	Semester 1 video title	Semester 2 video title
1	1	Elements and Atoms	Naming organic compounds
2	2	Molecules and Ions	Acidity of Organic Molecules and types of organic reactions
3	3	Chemical Equations	Introduction to Structure Determination
4	4	Stoichiometry	Naming Alcohols Amines and Halides
5	6	Atomic Energy Level	Assigning Priority and Absolute configuration
6	7	Molecular Shapes	Carbonyls and Acid Derivatives
7	8	Gas Law	Synthesis and Retrosynthesis
8	10	Thermodynamics	pH of strong Acids and Bases
9	11	Oxidation	Electronegativity and Bonding
10	13	Chemical Equilibrium or Electrochemistry	Coordination Numbers

Note. No weekly pre-learning materials take place during the weeks of the tutorial quizzes: week 5, week 9 and week 12 for junior courses.

Table 3.7. Weekly pre-learning materials video topics for intermediate chemistry courses across both semesters.

Pre-learning material	Week	Semester 1 video title	Semester 2 video title
1	2	Energy Profile Diagrams	Characteristic Temperature and the Partition function
2	3	Conformational Analysis	Vibrational Heat Capacity
3	4	Carbocations	The Clapeyron Equation
4	6	Directing Effects in S_EAr Reactions	Osmotic Pressure
5	7	The Mighty Carbonyl	Coordination Chemistry 1
6	8	Enols and Enolates	Coordination Chemistry 2
7	9	The Aldol Reaction	Organometallic Chemistry
8	11	Electromagnetism and Spectroscopy	Unit Cells and Lattice
9	12	Local Modes and Group Frequencies	Lattice Planes and Miller Indices
10	13	Vibronic Transitions	Condensed matter phase diagrams

Note. No weekly pre-learning materials take place during the weeks of the tutorial quizzes: week 5 and week 10 for intermediate courses.

3.11.2.2 Pre-learning quizzes

The pre-learning quizzes provide students with the opportunity to answer concept-building questions addressed in the weekly pre-learning videos. The quizzes are designed as a low-stake summative assessment targeting lower cognitive processing skills from Bloom's Taxonomy; a 1% mark is given for each quiz contributing a total of 10% to the final course grade. The mastery nature of these quizzes enables students to have multiple attempts within a given timeframe. The score of the last completed attempt is recorded in the students' grade book in the University's LMS. For each attempt, the pre-learning quiz questions follow the same order and structure. The questions are randomly selected form a large, purpose-build pool of questions developed by the chemistry teaching team. This ensures that if a student chooses to repeat a quiz, a different set of questions at the same level of difficulty will be generated.

The quizzes vary in length and format, consisting of a combination of 5-10 single best answer questions (SBAs), short answer questions (SAQs) or interactive drag and drop questions depending on the chemistry concept (Bokosmaty et al., 2019). SBAs are intended to expose misunderstanding students may have with a particular concept (Figure 3.3). SAQs are designed to either familiarise students with chemical terminology, or work through procedural steps to solve calculation-based questions (Figure 3.4). Drag and drop questions use visual learning aids to promote students' understanding of abstract chemistry concepts (Figure 3.5). Formative feedback is provided for each question irrespective of whether students selected the correct or incorrect answer to provide a brief explanation behind the underlying theory concepts.

Figure 3.4 is an example of the chemistry concepts previously included in the lecture component of the in-class sessions. By shifting this content to the online pre-learning materials, it enabled a full length of lecture content previously delivered in-class session prior to the partially flipped learning model implementation to be removed. By shifting naming inorganic nomenclator to the online pre-learning materials, students can master 'remembering' this concept, a lower cognitive processing skill, allowing for more time to be spent on active learning opportunities during the in-class session where students engage in higher cognitive processing skills as outlined by Bloom's Taxonomy.

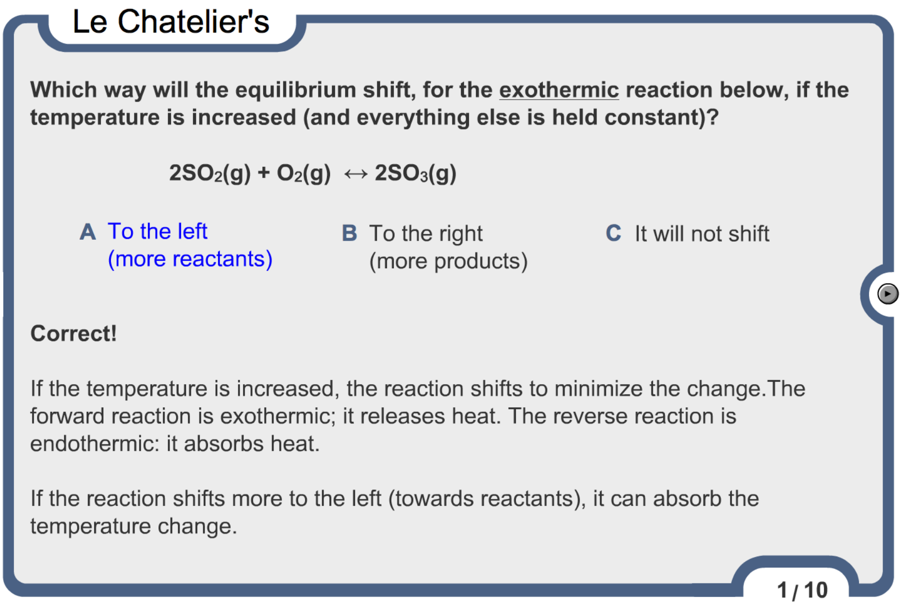

Figure 3.3. Example of weekly online quiz question formats and auto-generated feedback for single best answer question.

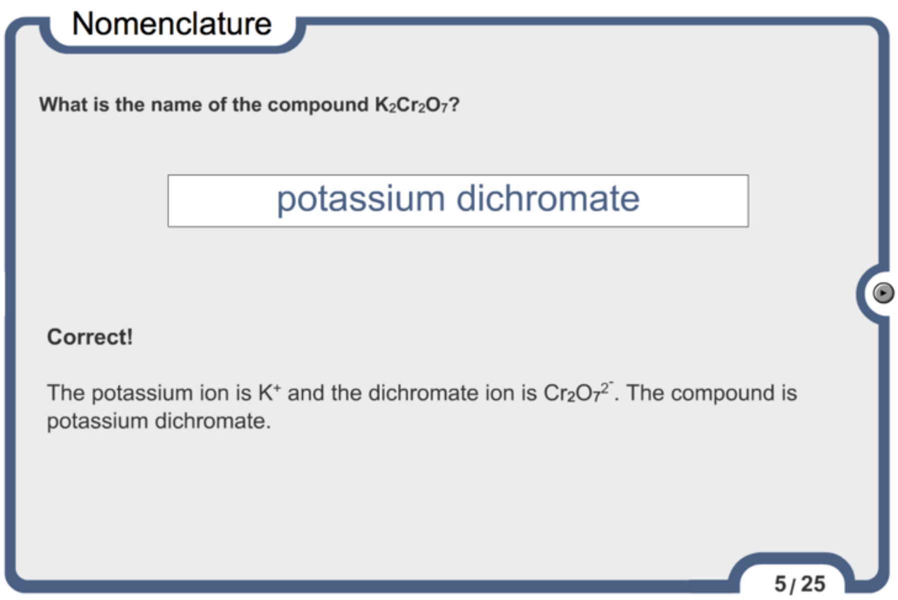

Figure 3.4. Example of weekly online quiz question formats and auto-generated feedback for short answer question.

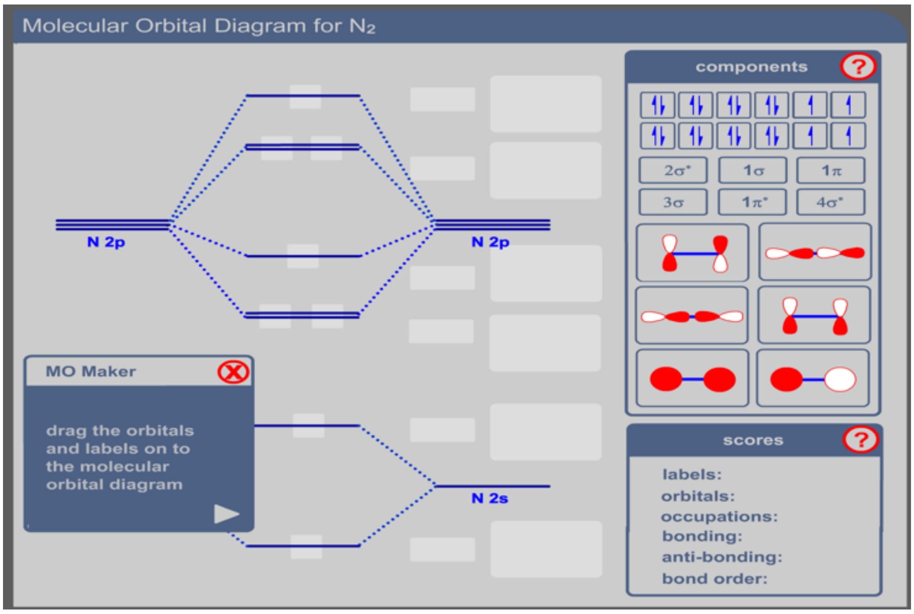

Figure 3.5. Example of weekly online quiz question formats and auto-generated feedback for drag and drop question.

3.12 Variation of the partially flipped learning model across the chemistry courses

The partially flipped learning model was initially introduced in 2013 for the fundamentals of chemistry course as part of a revised instructional approach to improve student engagement and academic performance in the junior chemistry courses. In 2015, the model was implemented in the mainstream and advanced junior chemistry courses. In 2016, the model was implemented in the core intermediate chemistry courses. The content delivered in the laboratory sessions is purposefully designed to be disconnected from the theory component delivered online and during the in-class sessions. The tutorial and laboratory sessions were not part of the revised curriculum and will not be discussed. The in-class sessions will also not be discussed further.

The same online pre-learning materials (videos and quizzes) were used across all three levels of junior chemistry courses. The courses have broadly similar learning outcomes but cater to students with different chemistry background (see section 3.9 for further details). However, since the partially flipped learning model was implemented semester by semester, the platform used for the pre-learning quizzes differed slightly between the semesters. For semester 1 the pre-learning quizzes were embedded as Flash-based modules whereas in semester 2, they were embedded using HyperText Markup Language (HTML) and Javascript. Due to these differences, it was not possible to collect data from junior chemistry courses to use for data tracking. For junior chemistry courses, no weekly pre-learning materials are presented during the weeks of the semester in which tutorial quizzes take place: week 5, week 9 and week 12.

The same online pre-learning materials (videos and quizzes) were used across all three levels of the intermediate chemistry courses. The courses have broadly similar learning outcomes but cater to students with different chemistry background (see section 3.10 for further details). The pre-learning quizzes across both semesters are embedded using HTML and Javascript. While the junior chemistry courses pre-learning quizzes varied in the number of questions (5-10 questions per quiz), there were 10 questions for each pre-learning quiz in the intermediate chemistry courses. The online pre-learning quizzes form part of the summative assessment (10% of the final course grade) for the normal and advanced intermediate chemistry courses. For the SSP intermediate chemistry courses, the online pre-learning materials are not compulsory; participation is voluntary, and no marks are rewarded for completion of pre-learning quizzes. For the intermediate chemistry courses, no weekly pre-learning materials are presented during the weeks in which the online in-semester tutorial quizzes take place: week 5 and week 10.

Since the junior chemistry courses have a larger cohort of students spread over several timetabled streams, quizzes are available for two weeks which accommodates for timetable variability and ensures equitable access to all students. As the intermediate chemistry courses have a smaller cohort, the period of availability for the quizzes is reduced to one week.

3.13 Data collection

This thesis reported on data collected from one cohort (Group A) of first year undergraduate students in junior chemistry courses and two cohorts (Group B_1 and Group B_2) of second year undergraduate students in intermediate chemistry courses (See Sections 3.8 and 3.9 for full description of the chemistry courses). Ethics approval was pending at various intervals throughout this doctoral research, so it was not always possible to collect data from all the junior and intermediate chemistry courses for all the above-mentioned research methods (See Sections 3.3.1-3.3.4 for full details regarding the data collection methods). Figure 3.6 summarises the data collection for Group A, Group B_1 and Group B_2 regarding students' approach to learning, perception towards online learning resources and interaction with the online component of the partially flipped learning model. As previously discussed, tracking data was gathered on a weekly basis, the R-SPQ-2F questionnaire was administrated at the start of semester 1 (week 2-3), the observational sessions and follow up interviews were conducted at various intervals throughout the semester and the perception questionnaire was carried out at the end of the semester (week 12-13).

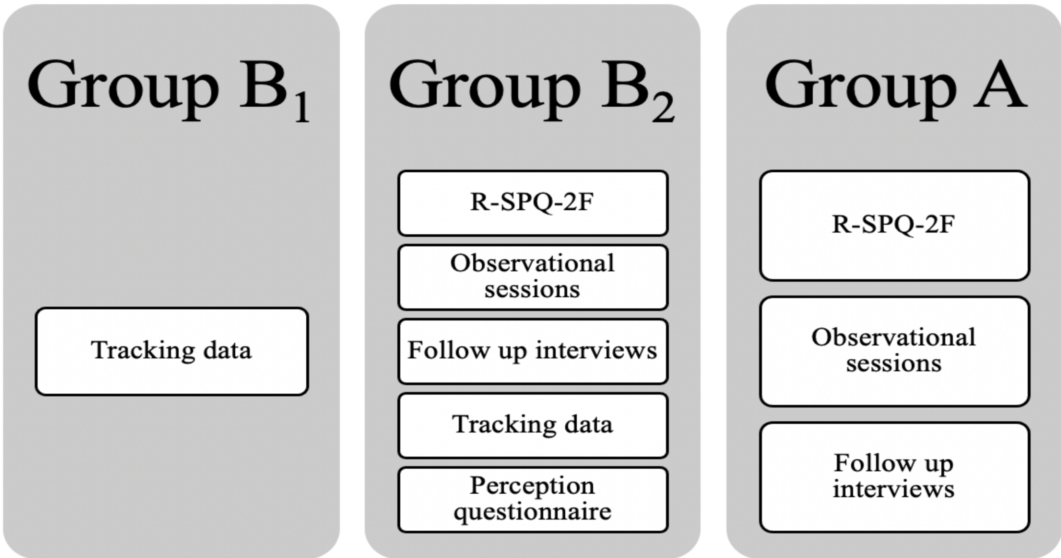

Figure 3.6. Data collection for the various chemistry groups reported on in this thesis.

Chapter 4: Behavioural engagement with the online component of a partially flipped learning model

4.1 Introduction

This chapter explores the relationship between students' behavioural engagement with the online component of the partially flipped learning model and their academic performance. Although this chapter focuses on behavioural engagement, it considers engagement as a multi-dimensional construct that encompasses three components: behavioural, emotional, and cognitive. This chapter draws on the definition proposed by the seminal work of Fredricks et al. (2004) and considers *behavioural engagement* the observable level a student participates and interacts with the learning activities. *Emotional engagement* entails students positive and negative affective reactions in a classroom towards their teachers, peers, and learning activities. *Cognitive engagement* relates to a student's psychological investment in and effort they are willing to direct towards learning to comprehend and master knowledge and skills.

There is substantial research evaluating the impact of a flipped learning environment on students' engagement and learning outcomes (Bancroft et al., 2021; Bredow et al., 2021; Burke & Fedorek, 2017; Cheng et al., 2019; O'Flaherty & Phillips, 2015). Findings related to learning outcomes as measured by academic performance, however, have been mixed, with some studies reporting significant improvements in academic performance (Cormier & Voisard, 2018; Eichler & Peeples, 2016; Flynn, 2015) whilst others have found no measurable differences with the implementation of a flipped learning model (Adams, Garcia, & Traustadóttir, 2016; Smallhorn, 2017; Yesterbsky, 2015). It has been proposed that a flipped learning environment has the potential to influence students' engagement levels (Seery, 2015). Diemer et al. (2013) suggest the need to separately analyse the impact of pre-class and in-class engagement on performance, as the two components (online and in-class) have distinct features and different learning requirements. Limited research on the online component, however, has examined the relationship between students' engagement and learning outcomes, with the majority focused on the in-class component (Meyliana et al., 2021; Smallhorn, 2017). Lee et al. (2018) examined the impact of learner engagement on students in general biology or chemistry flipped courses and found that both pre-class and in-class engagement were significant predictors for content/learning related outcomes, with a larger effect observed from the in-class engagement. The authors proposed a path diagram to show the effects different dimensions of engagement have on flipped learning outcomes. The three multi-dimensional constructs of engagement; behavioural, emotional, and cognitive, were positively interrelated, with behavioural engagement the "strongest indicator of success in terms of learning outcomes" (Lee et al., 2018, p. 225). In another study Lee and Choi (2019) observed in a life science course, a strong positive correlation between the two components of the flipped learning model. The result also indicates a strong positive correlation between the pre-learning component and final learning outcomes. This relationship was almost twice when comparing the effect of the in-class component on learning outcomes. Combined, these studies suggest that there is some evidence that students' behavioural engagement with the pre-learning materials may be a contributing factor that affects academic performance.

An early contribution to the field by Wang (2017) used learning analytics instead of self-reported measures to gather data on students' behavioural engagement. The design principles of the flipped learning model adopted by Wang were grounded in Merrill's framework (2013) that used a problem-centred learning approach to activate, demonstrate, apply, and integrate information. Self-reflection and self-assessment learning activities were also embedded in this design of the flipped learning model to further promote behavioural engagement with the online learning material and promote students' engagement with the problem-solving activities. It was observed that students' engagement with this problem-centric framework had a significant positive effect on formative assessment and overall academic achievement.

The design principles of the partially flipped learning model discussed in this thesis (see Section 3.11 for further details), however, differ from those of Wang (2017). This thesis uses learning analytics to provide a direct analysis of students' behavioural engagement with the main online learning resources, pre-learning videos and associated pre-learning quizzes, by using tracking data collected from the University's LMS throughout the semester. It was hypothesised that a higher level of engagement with the online components of the flipped learning model can lead to better academic performance compared to lower levels of engagement. The following research questions were examined:

1. What is the effect of students' behavioural engagement with the online learning component on their academic performance?
2. What are the factors that affect students' behavioural engagement with the online component?
3. How do changes in students' behavioural engagement across consecutive semesters affect their academic performance?

4.2 Methodology

4.2.1 Participants

The participants consisted of two groups of undergraduate chemistry students enrolled in intermediate chemistry courses in semesters 1 and 2. Group B_1 consisted of students enrolled in 2016 and Group B_2 consisted of students enrolled in 2017. The semester 1 intermediate courses were: Mainstream Molecular Reactivity and Spectroscopy (CHEM2401), Advanced Molecular Reactivity and Spectroscopy (CHEM2911) and Special Studies Program Molecular Reactivity and Spectroscopy (CHEM2915). The semester 2 intermediate courses were: Mainstream Chemical Structure and Stability (CHEM2402), Advanced Chemical Structure and Stability (CHEM2912) and Special Studies Program Chemical Structure and Stability (CHEM2916). See Section 3.9 for a full description for each of the chemistry courses.

4.2.2 Procedure

The engagement index was developed using the aggregated data of students' weekly behavioural engagement with the online pre-learning materials across the three intermediate chemistry courses over the course of a semester. For Group B_1, data were collected for the intermediate chemistry courses during semester 1 (n = 262) and semester 2 (n = 179). For Group B_2, data were collected for the intermediate chemistry courses during semester 1 (n = 247) and semester 2 (n = 175).

Students' online behavioural engagement with each of the weekly pre-learning materials was captured in a real-time manner in the University's LMS, with LMS click data recoded via a bespoke software (see Section 3.3.2 for more details regarding the use of tracking data). To measure students' video-viewing behaviours, tracking data captured the frequency of views and the time of access for each video. It did not, however, capture the length of views for each video. To measure students' behavioural pattern with the pre-learning quizzes, tracking data captured students' frequency of access, time of access for each attempt, score for each attempt, the number of questions completed for each attempt, the time spent to select an answer and the time spent reading the feedback provided. The gathered tracking data were exported as a .csv file and then imported into excel to identify weekly trends in students' interaction with each of the pre-learning materials by analysing the time of access, the total frequency of access, mean quiz score, median/mean time spent on each question, feedback, and the overall quiz. Section

4.3 provides further details on which parameters were used for developing an index that measures students' online engagement with the pre-learning materials.

4.3 Development of the Engagement Index

Following the method of Babbie (2012), an index was developed to measure students' behavioural engagement with the online pre-learning materials. The index was developed by combining multiple items into a single composite measure. Each item selected measures a different aspect of the ways in which students engaged with the video or quiz. There are two main reasons for developing an index using composite items instead of examining single items. Firstly, individually analysing items may not adequately represent students' overall engagement. This may lead to invalid or unreliable inferences being made about students' engagement. Secondly, an index formed by combining several items can measure students' online engagement in numerous ordinal categories from low to high level, which might not have otherwise been achievable when examining individual items.

The following section will detail the main steps required for constructing an engagement index: selecting items, examining the empirical relationship between items, scoring and weighting of items, managing missing data, and validating the index (Babbie, 2012).

4.3.1 Selection of items

In selecting the items for constructing a composite index to measure students' online engagement with pre-learning videos and pre-learning quizzes, it is essential to consider four key components (Babbie, 2012). The first component is *face/logical validity*, which requires that all items related to measuring students' online engagement must be considered. Secondly, it is important for the composite measure to be *unidimensional* by focusing only on the items related to students' online engagement. Thirdly, the items can be *specific* or *general* depending on the variable being measured. In this case, to measure students' online engagement, specific items were selected and were exclusively related to the videos and quiz instead of being general. Finally, the level of *variance* of each item is considered to determine whether an item is useful in the construction of the index. Variance in the items selected can be achieved in two ways. For example, the selected items can divide the students equally, i.e., approximately half of the students watched the video and half did not. Although no observation on a single item would justify the classification of a person as engaged, a person who was observed to engage on all items might be classified as engaged. Another way is to select items that differ in variance, i.e., one item might identify approximately half of the students as engaged, while another might identify few of the students as engaged. In either case, all items must have sufficient variance to be statistically valid.

The items chosen for creating the engagement index were in part informed by the existing literature and an understanding of the design features embedded in the pre-learning materials reported on in this thesis (See Sections 2.5.6.1 and 2.5.10 for more details regarding engagement parameters and students' behavioural engagement with the pre-learning materials). A commonly reported parameter to measure students' video-viewing behaviours and interactions with the pre-learning quizzes is the frequency of *access* (Beatty et al., 2019; Dazo et al., 2016; Lacher & Lewis, 2014). This parameter provides valuable insight on how often the students' watched the assigned pre-learning videos and how many times the students' have chosen to attempt the pre-learning quizzes. In addition, the *score* for each pre-learning quiz accessed was recorded. This provides another facet to understanding students' online behavioural engagement, as it can give an indication on how students were performing, and further inferences can be drawn on whether the number of pre-learning quizzes accessed can impact students' performance in them. Another reported measure to monitor students' behavioural engagement is *time spent* on a certain task (Tasker et al., 2003). Due to the design of the online pre-learning quizzes implemented in the described partially flipped learning model, it was possible to measure the *time spent* on each pre-learning quiz attempt and the embedded feedback. The parameter related to the *time spent* on feedback offers a distinct insight on students' behavioural engagement and indicate whether students used the feedback provided as a reflective tool to aid them in answering the questions.

To gain a holistic understanding of students' behavioural engagement the index developed in was composed of one item related to the pre-learning video and four items related to the pre-learning quizzes.

1. *nvideo*: total number of pre-learning videos viewed by each student
2. *mtquiz*: median time spent per attempted pre-learning quiz by each student
3. *asquiz*: average score of the total number of attempted pre-learning quizzes by each student
4. *afquiz*: average time spent on feedback of the total number of attempted pre-learning quizzes
5. *nquiz:* total number of attempted pre-learning quizzes by each student

4.3.2 Empirical relationship between items

A bivariate relationship was used to determine the relative strength amongst the items considered for inclusion in the engagement index (Babbies, 2012). The Spearman rank correlation coefficient, ρ, was used to determine the degree to which the items were related by measuring the strength and direction. The Spearman rank correlation range from -1 to +1 with negative values implying negative correlations, positive values implying positive correlations and zero value indicating no correlation between the variables (Ratner, 2008).

As shown in Table 4.1, when examining the bivariate relationship between the *nvideo* item and each of the other four items related to the quiz, there was a weak but positive correlation. This might be because the videos and the quizzes are separate components of the online learning platform and they each provide a different facet of students' behavioural engagement.

The bivariate relationship amongst the other four pre-learning quiz items revealed valuable features related to behavioural engagement. The *mtquiz* item reflects the amount of time a student spent on attempting a quiz. A positive relationship is observed between *mtquiz* and *asquiz* as well as between *mtquiz* and *afquiz.* It may be assumed that students taking a longer time to complete tend to be more engaged as they may be carefully considering the questions and the feedback provided to achieve a high score. The *afquiz* item suggests that students who spend more time than the threshold value reading the feedback tend to be more engaged. A negative relationship is observed between *nquiz* and *afquiz* which suggests that students who do not engage with the feedback and have multiple attempts at the quiz are not engaging with the material. A positive relationship is observed between *asquiz* and *afquiz* which suggests that students who engage with the feedback may not require as many attempts. Their use of the feedback may have led to a stronger understanding of the material and thus fewer pre-learning quiz attempts to achieve a high score. A strong negative relationship is observed between *asquiz* and *nquiz,* suggesting that having multiple quiz attempts without engaging with feedback can lead to a lower score. The *nquiz* is thus assumed to be an engagement measure. The *asquiz* was used instead of the final quiz score due to their mastery nature as majority of students would attain a final score of ten irrespective of how many attempts they may have made. As such, the *asquiz* provides a better indicator of engagement when comparing it to the *nquiz.*

Table 4.1. Bivariate relationship among index items.

Item pairs	Item names	Spearman rank coefficient (ρ)
1 and 2	nvideo and mtquiz	0.052
1 and 3	nvideo and asquiz	0.098
1 and 4	nvideo and afquiz	0.062
1 and 5	nvideo and nquiz	0.009
2 and 3	mtquiz and asquiz	0.283**
2 and 4	mtquiz and afquiz	0.145*
2 and 5	mtquiz and nquiz	-0.203
3 and 4	asquiz and afquiz	0.373**
3 and 5	asquiz and nquiz	-0.793**
4 and 5	afquiz and nquiz	-0.154*

Note. *p < 0.05 ** p < 0.01. Bivariate analysis based on aggregated data from the intermediate chemistry courses.

4.3.3 Scoring and weighting of items

To create a single composite index made from several items, scores and weightings were assigned for each of the five items. Descriptive statistics were calculated for each item to measure the central tendency and variability of the data (see Section 3.4 in the methodology for further details).

To group students based on their level of interactions with the online pre-learning materials, an inter-limit value of 0, 1 or 2 was allocated on a weekly basis for each of the five items. To calculate the cut-off of these inter-limit values, the students' interaction data (tracking data) for each item was divided into three-percentile group so that an inter-limit value of 0, 1 or 2 can be assigned to one of the three engagement groups: low, moderate, and high. The use of the percentiles provides meaningful benchmarking across each of the items. The data was purposely divided into three-percentile groups to be assigned to one of the three engagement groups, and while this is subjective it provided an appropriate sample size for the analysis to be carried out. Creating more groups would have led to a smaller sample size in each engagement group and limited the statistical power for detecting population differences between the groups (Leppink, et al., 2016).

The assignment of the inter-limit value for each item was based on the hypotheses assumptions made regarding students' behavioural engagement (see Table 4.2) and an understanding of the items themselves. For instance, for the *mtquiz, asquiz and afquiz* items, the low engagement group included values below the 33rd percentile, the moderate engagement group included values ranging between the 33rd percentile and 66th percentile, and the high engagement group included values above the 66th percentile. For the *nquiz* item, the low engagement group included values above the 66th percentile, the moderate engagement group included values ranging between the 33rd percentile and 66th percentile, and the high engagement group included values below the 33rd percentile. For these four items a score of 0, 1 or 2 was assigned for the low, moderate, and high engagement groups respectively. It was not possible to score the *nvideo* item based on percentile values since the 33rd and 66th percentile values were the same. Students who did not watch the pre-learning video were assigned a score of 0, those that watched it once or twice were assigned a score of 1 and those students that watched it more than twice were assigned a score of 2. For this item a score of 0, 1 or 2 was assigned for the low, moderate, and high engagement groups respectively.

As each item contributes to measuring students' behavioural engagement with the online resources, each item was given an equal weighting, multiplier of 1 (Babbie, 2012).

Table 4.2. Hypotheses regarding students' behavioural engagement with the online learning resources.

Item	Low engagement	Moderate/High engagement
nvideo	H_0: Students that do not watch the pre-learning videos tend to be less engaged	H_1: Students that watch the pre-learning videos tend to be more engaged
mtquiz	H_0: Students that spend less than the threshold time* answering the pre-learning quizzes tend to be less engaged	H_1: Students that spend a certain threshold time* answering the pre-learning quizzes tends to be more engaged
asquiz	H_0: Students that have a lower average than the threshold value* score tend to be less engaged	H_1: Students that have a higher average score than the threshold value* tend to be more engaged
afquiz	H_0: Students that spent less time than the threshold value* reviewing feedback for questions answered (correctly or incorrectly) tend to be less reflective and less engaged	H_1: Students that spend more time than the threshold value* reviewing feedback for questions answered (correctly or incorrectly) tend to be more reflective and more engaged
nquiz	H_0: Students that attempt the pre-learning quiz more times than the threshold value* tend to be less engaged	H_1: Students that attempt the pre-learning quiz fewer times than the threshold value* tend to be more engaged

Note. *Threshold values are based on the percentile values determined for each item.

4.3.4 Managing missing data

There were no missing data. Students' online interactions over the ten weekly pre-learning materials were compiled for both groups.

4.3.5 Validity and reliability of the index

The index was validated internally and externally using the method suggested by Babbie (2012). To internally validate an index, item analysis was used to examine the "extent to which the index is related to (or predicts responses to) the individual" (Babbie, 2012, p. 169) items it comprises. This approach assesses whether each of the items included in developing this composite index "makes an independent contribution or merely duplicates the contribution of other items in the measure" (Babbie, 2012, p. 169).

To internally validate the engagement index, the independent contribution for each item was determined. Table 4.3 shows an example of the weekly independent contribution for each of the five items based on the inter-limit scores outlined in Section 4.3.3. The percentages represent the distribution of students across each of the three engagement groups for the five items that comprised the index. For example, for the *nvideo,* 22% of students were categorised in the low engaged group, 58% of students were categorised in the moderately engaged group, whereas 20% of students were categorised in the highly engaged group based on the assigned inter-limit scores discussed in Section 4.3.3. For the *mtquiz, asquiz and afquiz* items similar percentages in the distribution of students were observed across each of the three groups of engagement. For the *nquiz*, 52% of students were categorised in the low engaged group, 22% of students were categorised in the moderately engaged group, whereas 26% of students were categorised in the highly engaged group based on the assigned inter-limit scores discussed in Section 4.3.3.

The items appear to be an appropriate component of the engagement index, since each individual item reflects similar measures to what the composite index aims to measure (Babbie, 2012).

Table 4.3. Item analysis of the various composite measures that comprise the engagement index.

	Engagement index score		
Items	LE (%)	ME (%)	HE (%)
nvideo	22	58	20
mtquiz	42	29	29
asquiz	37	30	33
afquiz	42	29	29
nquiz	52	22	26

Note. LE = low engagement, ME = moderate engagement and HE = high engagement. The percentages represent the distribution of students in each engagement group across the various items of the engagement index (Group B_1, semester 1, week 1).

To externally validate the engagement index, an item that was not previously included in the development of the index was selected. The item used was the average number of questions accessed per pre-learning quiz attempt by each student, another potential measure of students' online engagement. It is hypothesised that students who have answered more questions than the threshold number tend to be more engaged with the learning resources compared to those that have answered less than the threshold number of questions.

The reliability of the engagement index was considered by repeating the same steps outlined in Section 4.3 for both Groups B_1 and B_2. In addition, the same bespoke software was used to extract the tracking data for the identified items used to measure students' behavioural engagement.

4.3.6 Overall Engagement Index

A composite engagement index score for each student was calculated by summing the inter-limit values obtained on each of the five items across the ten weeks (as discussed in Section 4.3.3). For example, for the *nvideo* item, a student was assigned an inter-limit value between 0 and 2 on a particular week based on the percentile values determined for the group. As such, a student may be assigned a score of 0 for a given week but a score of 1 or 2 for another week. By the end of the ten weeks a student obtained a score out of twenty since the maximum inter-limit value range is 2. The process is repeated for the other four items where the students will obtain a maximum score of twenty per item. The scores for all five items were aggregated so that each student obtained a cumulative item score ranging from 0 to 100. Students were divided into three engagement groups (low, moderate, and high) based on their cumulative item scores. The three engagement groups were determined by using percentiles to provide meaningful benchmarking across each of the three groups.

4.4 Results

4.4.1 Participation rates for intermediate chemistry courses

The overall participation rate and that of each of the three intermediate chemistry courses for Group B_1 and Group B_2 across both semesters are shown in Table 4.4 and Table 4.5 respectively.

For Group B_1, a total of 143 (49%) students completed both semester 1 and semester 2 intermediate chemistry courses. For Group B_2, a total of 124 (37%) students completed both semester 1 and semester 2 intermediate chemistry courses. When comparing the participants of Group B_1 and Group B_2, 8 students were common across both groups for semester 1, whereas 4 students were common across both groups for semester 2.

Table 4.4. Participation rate by intermediate chemistry course in Group B_1 across both semesters.

	Semester 1			Semester 2	
	Participants	Participation rate		Participants	Participation rate
	n	%		*n*	%
CHEM2401	172	97	CHEM2402	97	80
CHEM2911	81	100	CHEM2912	76	97
CHEM2915	9	38	CHEM2916	6	46
Total	262	93	Total	179	84

Table 4.5. Participation rate by intermediate chemistry course in Group B_2 across both semesters.

	Semester 1			Semester 2	
	Participants	Participation rate		Participants	Participation rate
	n	%		*n*	%
CHEM2401	155	87	CHEM2402	120	93
CHEM2911	60	97	CHEM2912	43	100
CHEM2915	20	91	CHEM2916	11	58
Total	235	90	Total	174	90

4.4.2 Comparison of student groups

To compare the performance of Group B_1 with Group B_2 in each semester, it is necessary to determine that there is a homogeneity of variances, indicating that the variance of Group B_1 with Group B_2 is the same for each semester. The weighted average mark (WAM) score was used to draw comparisons between the various groups (see Table 4.6). A WAM score for a student is a weighted average mark of all the completed courses. At the University of Sydney, weighting for a course is based on its credit point value and year level of the course completed. Junior units are weighted one, intermediate units are weighted two and senior units are weighted three. Students completing intermediate chemistry courses would have completed two junior chemistry courses (6 credit points, level 1000), and other first year junior courses (either 3 or 6 credits, level 1000).

Table 4.6. Cohort response rate for students with WAM score across all three intermediate chemistry courses in Groups B_1 and B_2.

	Semester 1		Semester 2	
	Respondents with WAM	Response rate	Respondents with WAM	Response rate
	n	%	*n*	%
Group B_1	219	84	158	88
Group B_2	200	85	134	77

The results for semester 1 indicated that there was no significant difference in the WAM score between students in Group B_1 and Group B_2 ($t_{417} = 1.74$, $p = 0.083$). The results for semester 2 indicated that there was no significant difference in the WAM score between students in Group B_1 and Group B_2 ($t_{290} = 0.8$, $p = 0.936$). These results suggest that comparison between groups during semester 1 and 2 can be carried out as the variance was similar and no statistical significance was observed in the WAM scores (see Table 4.7).

Table 4.7. Mean WAM scores to determine sample representation of the Groups B_1 and B_2.

	Semester 1			Semester 2		
	n	M	SD	*n*	M	SD
Group B_1	219	68.93	10.60	158	70.18	9.29
Group B_2	200	70.82	11.69	134	70.27	11.60

Note. M = mean, SD = standard deviation.

4.4.3 Overall Engagement Index

4.4.3.1 Intermediate chemistry Group B_1

The engagement index score for students in Group B_1 that completed all 10 weekly pre-learning materials across semester 1 and 2 for 2016 was collated into a histogram (see Figure 4.1). The Shapiro-Wilk test of normality was used to determine if the engagement index scores were normally distributed. This test was used instead of Kolmogorov-Smirnov as it is more appropriate for sample sizes smaller than 2000 (Zimmerman, 2004). The engagement index scores were found to be normally distributed: semester 1 (W [262] = 0.99, $p > 0.01$) and semester 2 (W [179] = 0.99, $p > 0.01$). The means and standard deviations for each semester are represented in Table 4.8.

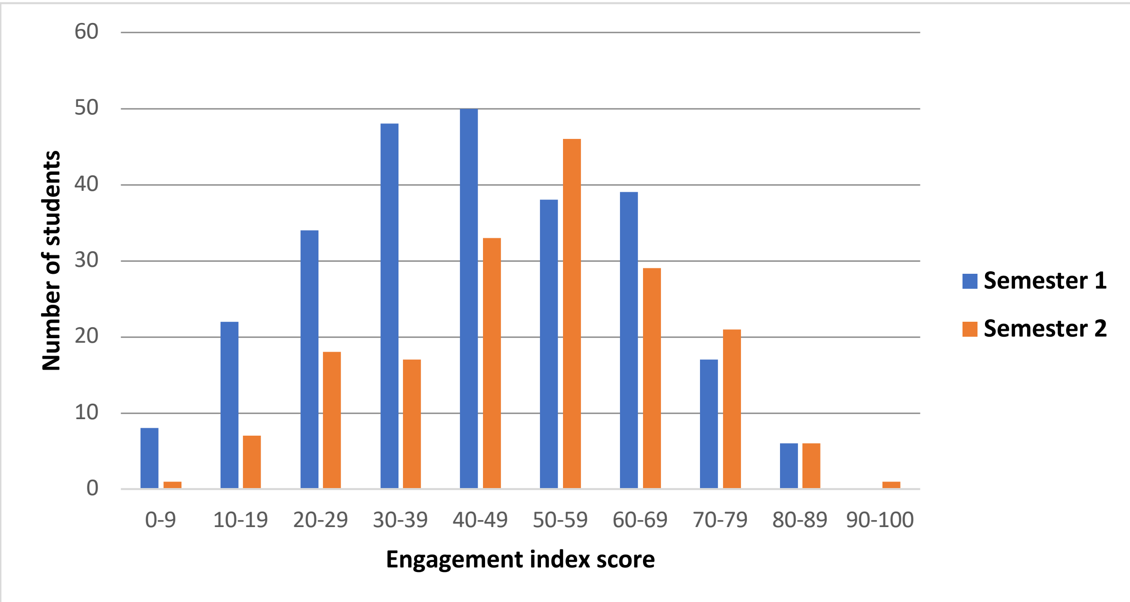

Figure 4.1. Distribution of engagement index score for students across all three intermediate chemistry courses in semester 1 (n = 262) and semester 2 (n = 179) for Group B_1.

Table 4.8. Means and Standard Deviation for engagement index score for Group B_1.

	Engagement index score		
	n	M	SD
Semester 1	262	43.76	18.74
Semester 2	179	51.25	17.68

Note. M = mean, SD = standard deviation.

The three engagement groups were obtained using the same method outlined in Section 4.3.3 by calculating three-percentile groups for the engagement index score to form the three groups: low engagement, moderate engagement, and high engagement. The inter-limit values used are outlined in Table 4.9. The distribution of the engagement index scores across each of the chemistry course in Group B_1 are presented in Table 4.10.

Table 4.9. Inter-limit values for the engagement groups across all three intermediate chemistry courses in Group B_1 for both semesters.

	Engagement group		
	LE	ME	HE
Semester 1	≤ 34	34 < Score ≤ 52.33	> 52.33
Semester 2	≤ 45	45 < Score ≤ 58	>58

Note. LE = low engagement, ME = moderate engagement and HE = high engagement Semester 1(n = 262) semester 2 (n = 179).

Table 4.10. Distribution of the engagement index score across the various chemistry courses for Group B_1.

	Semester 1				Semester 2		
	n				*n*		
	LE	ME	HE		LE	ME	HE
CHEM2401	63	55	54	CHEM2402	39	31	27
CHEM2911	20	29	32	CHEM2912	21	24	31
CHEM2915	5	3	1	CHEM2916	3	2	1
Total	88	87	87	Total	63	57	59

Note. LE = low engagement, ME = moderate engagement and HE = high engagement.

4.4.3.2 Intermediate chemistry Group B_2

The engagement index score for students in Group B_2 that completed all 10 weekly pre-learning materials across semester 1 and 2 for 2017 was collated into a histogram (see Figure 4.2). The Shapiro-Wilk test of normality was used to determine if the engagement index scores were normally distributed. The engagement index scores were found to be normally distributed: semester 1 (W [235] = 0.99, p > 0.01) and semester 2 (W [175] = 0.98, p > 0.01). The means and standard deviations for each semester are represented in Table 4.11.

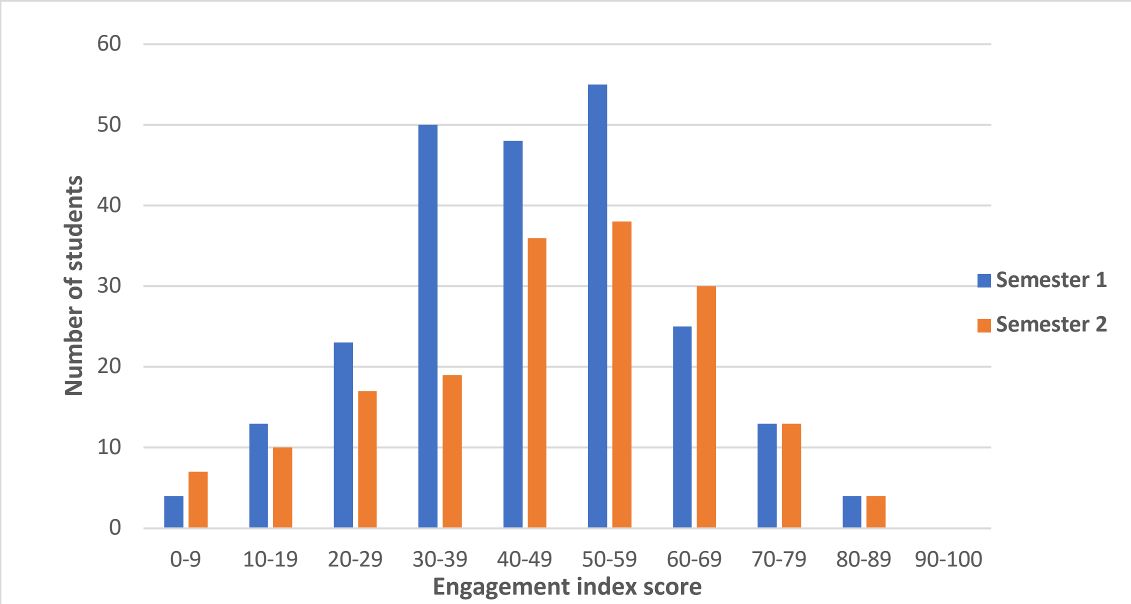

Figure 4.2. Distribution of engagement index score for students across all three intermediate chemistry courses in semester 1(n = 235) and semester 2 (n = 174) for Group B_2.

Table 4.11. Means and Standard Deviation for engagement index score for Group B_2.

	Engagement index score		
	n	M	SD
Semester 1	235	54.74	18.98
Semester 2	174	46.99	18.62

Note. M = mean, SD = standard deviation.

The three engagement groups were obtained using the same method outlined in Section 4.3.3 by calculating three-percentile groups for the engagement index score to form the three groups: low engagement, moderate engagement, and high engagement. The inter-limit values used are outlined in Table 4.12. The distribution of the engagement index scores across each of the chemistry courses in Group B_2 are presented in Table 4.13.

Table 4.12. Inter-limit values for the engagement groups across all three intermediate chemistry courses in Group B_2 for both semesters.

	Engagement group		
	LE	ME	HE
Semester 1	≤ 38	38 < Score ≤ 54	> 54
Semester 2	≤ 41	42 < Score ≤ 56	>56

Note. LE = low engagement, ME = moderate engagement and HE = high engagement. Semester 1 (n = 235) and semester 2 (n = 174).

Table 4.13. Distribution of the engagement index score across the various chemistry courses for Group B_2.

	Semester 1				Semester 2		
	n				*n*		
	LE	ME	HE		LE	ME	HE
CHEM2401	49	55	51	CHEM2402	34	49	37
CHEM2911	19	23	18	CHEM2912	18	11	14
CHEM2915	14	1	5	CHEM2916	7	1	3
Total	82	79	74	Total	59	61	54

Note. LE = low engagement, ME = moderate engagement and HE = high engagement.

4.4.4 Engagement index and academic performance

4.4.4.1 Academic performance at a cohort level for Group B_1 across semesters

The data for academic performance were initially analysed at a cohort level by combing all intermediate chemistry students in Group B_1 for a given semester to holistically examine the impact of the model. Appendix F shows the relationship between students' academic performance in the online pre-learning quizzes with each of the following: in-semester quizzes, end of semester examination, theory component (combines the scores for the online pre-learning quizzes, in-semester quizzes, and end of semester examination), laboratory component, and the final course performance (combines the scores for the theory component and the laboratory component).

It is interesting to note that for Group B_1 there was some correlation between students' academic performance in the online pre-learning quizzes and the in-semester quizzes. A correlation was also observed between students' academic performance in the online pre-learning quizzes and laboratory component. Although this reflects engagement, the tutorial sessions were not part of the revised curriculum and will not be discussed further. In addition, content delivered in the laboratory sessions is purposefully designed to be disconnected from the theory component delivered online and during the in-class sessions. These correlations were not investigated further. A one-way ANOVA was carried out to investigate the academic performance of all intermediate chemistry students in each of the end of semester examination as it contributes to 60% of the final course grade (see Section 4.4.4.1.1). Another one-way ANOVA was conducted to investigate students' course performance in the theory component as measured by combining their scores for the online pre-learning quizzes, in-semester quizzes, and end of semester examination as it contributes to 85% of the final course grade (see Section 4.4.4.1.2).

The following sections report on one-way ANOVA analyses carried out to investigate the academic performance of students across the three engagement groups. Table 4.14 provides a summary of the results obtained from the one-way ANOVA analyses and post-hoc Tukey's *t*-tests by identifying the significant differences in academic performance observed among the engagement groups for Group B_1 across both semesters. Appendix G (Tables G.1 to G.8) provides more details regarding the individual one-way ANOVA analyses and post-hoc Tukey's *t*-test comparison for the end of semester examination and overall theory course performance carried out on a cohort and course level for both groups across the semesters.

4.4.4.1.1 Academic performance in end of semester examination

A one-way ANOVA showed a significant difference among the three engagement groups for semester 1 [$F_{2,259} = 12.245$, $p < 0.001$] and semester 2 [$F_{2, 176} = 7.055$, $p < 0.001$]. For semester 1, post-hoc Tukey's *t*-test indicated that the mean examination score for low engaged students was significantly lower compared to those that are in the moderately engaged and highly engaged group. For semester 2, post-hoc Tukey's *t*-test indicated that the mean examination score for low engaged students was significantly lower than those in the highly engaged group. However, no significant difference was observed between the other engagement groups in both semesters (see Tables G.1 and G.2).

4.4.4.1.2 Overall theory course performance

A one-way ANOVA showed a significant difference among the three engagement groups for semester 1 [$F_{2, 259} = 16.492$, $p < 0.001$] and semester 2 [$F_{2, 176} = 10.460$, $p < 0.001$]. For both semesters, post-hoc Tukey's *t*-test indicated that the overall theory course performance for low engaged students was significantly lower compared to those that are in the moderately engaged and highly engaged group. However, no significant difference was observed between the other engagement groups in both semesters (see Table G.3 and Table G.4).

4.4.4.2 Academic performance at a course level for Group B_1 semester 1

The results for Group B_1 at a cohort level showed a significant difference among the three engagement groups in the end of semester examination and overall theory course performance for both semesters (see Tables G.1 to Table G.4). All further data were analysed separately for each chemistry course rather than being combined to observe the impact of the model on students of varying proficiency level in chemistry.

4.4.4.2.1 Academic performance in CHEM2401

A one-way ANOVA revealed that there was a significant difference in the end of semester examination score [$F_{2, 169} = 10.676$, $p < 0.001$] and the overall theory course performance [$F_{2, 169} = 14.869$, $p < 0.001$, $d = 0.150$] among the three engagement groups (see Table G.5). A post-hoc Tukey's *t*-test indicated that the mean scores for the end of semester examination and the overall theory course performance for low engaged students was significantly different to those that are in the moderately and highly engaged groups.

4.4.4.2.2 Academic performance in CHEM2911

A one-way ANOVA revealed that there was no significant difference in the end of semester examination score [$F_{2, 78} = 2.691$, $p = 0.074$] but a significant difference was observed in the overall theory course performance [$F_{2, 78} = 3.369$, $p = 0.039$] among the three engagement groups (see Table G.6).A post-hoc Tukey's *t*-test indicated that the mean score for the overall theory course performance for low engaged students was significantly lower than those that are in the highly engaged group.

4.4.4.2.3 Academic performance in CHEM2915

A one-way ANOVA revealed that there was a significant difference in the end of semester examination score [$F_{2, 6} = 5.820$, $p = 0.039$] and the overall theory course performance [$F_{2, 6} = 5.693$, $p = 0.041$] among the three engagement groups. However, post-hoc Tukey's *t*-test was not performed as one group had fewer than two cases.

4.4.4.3 Academic performance at a course level for Group B_1 semester 2

4.4.4.3.1 Academic performance in CHEM2402

A one-way ANOVA revealed that there was a significant difference in the end of semester examination score [$F_{2, 94}$ = 5.944, p = 0.004] and the overall theory course performance [$F_{2, 94}$ = 7.781, p = 0.001] among the three engagement groups (see Table G.7). A post-hoc comparison using the Tukey's *t*-test indicated that the mean scores for the end of semester examination and the overall theory course performance for highly engaged students was significantly higher than those that are in the low engaged and moderately engaged.

4.4.4.3.2 Academic performance in CHEM2912

A one-way ANOVA revealed that there was a significant difference in the end of semester examination score [$F_{2, 73}$ = 3.865, p = 0.025] and overall theory course performance [$F_{2, 73}$ = 3.865, p = 0.009] among the three engagement groups (see Table G.8). A post-hoc Tukey's *t*-test indicated that the mean score for the end of semester examination for low engaged students was significantly lower than those that are moderately engaged. Post-hoc Tukey's *t*-test also indicated that the mean score for the overall theory course performance for low engaged students was significantly lower than those that are moderately engaged and highly engaged students.

4.4.4.3.3 Academic performance in CHEM2916

A one-way ANOVA revealed that there was no significant difference in the end of semester examination score [$F_{2, 5}$ = 1.058, p = 0.449] and overall theory course performance [$F_{2, 5}$ = 1.018, p = 0.460] among the three engagement groups.

Table 4.14. Engagement pairs showing significant differences in academic performance for Group B_1 according to a one-way ANOVA analyses and post-hoc Tukey's *t*-test results.

	Semester 1			Semester 2	
	End of semester examination	Overall theory course performance		End of semester examination	Overall theory course performance
Cohort	• LE and ME • LE and HE	• LE and ME • LE and HE	Cohort	• LE and HE	• LE and ME • LE and HE
CHEM2401	• LE and ME • LE and HE	• LE and ME • LE and HE	CHEM2402	• LE and HE • ME and HE	• LE and ME • LE and HE
CHEM2911	• NS	• LE and HE	CHEM2912	• NS	• LE and ME • LE and HE
CHEM2915	• NS	• NS	CHEM2916	• NS	• NS

Note. NS = no significance, LE = low engagement, ME = moderate engagement and HE = high engagement.

4.4.4.4 Academic performance at a cohort level for Group B_2 across semesters

The data for academic performance were initially analysed at a cohort level by combing all intermediate chemistry students in Group B_2 for a given semester to holistically examine the impact of the model. Appendix H shows the relationship between students' academic performance in the online pre-learning quizzes with each of the following: in-semester quizzes, end of semester examination, theory component (combines the scores for the online pre-learning quizzes, in-semester quizzes, and end of semester examination), laboratory component, and the final course performance (combines the scores for the theory component and the laboratory component).

It is interesting to note that for Group B_2 there was some correlation between students' academic performance in the online pre-learning quizzes and the in-semester quizzes. A correlation was also observed between students' academic performance in the online pre-learning quizzes and laboratory component. As noted for Group B_1, the tutorial sessions were not part of the revised curriculum and content delivered in the laboratory sessions is purposefully designed to be disconnected from the theory component delivered online and during the in-class sessions These correlations were not investigated further.

A one-way ANOVA was carried out to investigate the academic performance of all intermediate chemistry students in each of the end of semester examination as it contributes to 60% of the final course grade (see Section 4.4.4.4.1). Another one-way ANOVA was conducted to investigate students' course performance in the theory component as measured by combining their scores for the online pre-learning quizzes, in-semester quizzes, and end of semester examination as it contributes to 85% of the final course grade (see Section 4.4.4.4.2).

The following sections report on one-way ANOVA analyses carried out to investigate the academic performance of students across the three engagement groups. Table 4.15 provides a summary of the results obtained from the one-way ANOVA analyses and post-hoc Tukey's *t*-tests by identifying the significant differences in academic performance observed among the engagement groups for Group B_1 across both semesters. Appendix I (Table I.1-I.8) provides more details regarding the individual one-way ANOVA analyses and post-hoc Tukey's *t*-test comparison for the end of semester examination and overall theory course performance carried out on a cohort and course level for both groups across the semesters.

4.4.4.4.1 Academic performance in end of semester examination

A one-way ANOVA results showed a significant difference among the three engagement groups for semester 1 [$F_{2, 232} = 9.729$, $p < 0.001$] and semester 2 [$F_{2, 171} = 6.723$, $p = 0.002$]. A post-hoc Tukey's *t*-test indicated that the mean score for the end of semester examination for low engaged students was significantly lower than those in the highly engaged group in both semesters. However, no significant difference was observed between the other engagement groups in both semesters (see Table I.1 and Table I.2).

4.4.4.4.2 Overall theory course performance

A one-way ANOVA showed a significant difference among the three engagement groups for semester 1 [$F_{2, 232} = 12.325$, $p < 0.001$] and for semester 2 [$F_{2, 171} = 8.094$, $p < 0.001$]. A post-hoc Tukey's *t*-test indicated that the overall theory course performance for highly engaged students was significantly higher than those in the low and moderately engaged group for both semesters. However, no significant difference was observed between the other engagement groups for both semesters (see Table I.3 and Table I.4).

4.4.4.5 Academic performance at a course level for Group B_2 semester 1

The results for Group B_2 at a cohort level showed a significant difference among the three engagement groups in the end of semester examination and overall theory course performance for both semesters (see Tables I.1 to Table I.4). All further data were analysed separately for each chemistry course rather than being combined to observe the impact of the model on students with varying proficiency levels in chemistry.

4.4.4.5.1 Academic performance in CHEM2401

A one-way ANOVA revealed that there was a significant difference in the end of semester examination score [$F_{2, 152} = 18.278$, $p < 0.001$] and the overall theory course performance [$F_{2, 152} = 23.376$, $p < 0.001$] among the three engagement groups (see Table I.5). A post-hoc Tukey's *t*-test indicated that the mean scores for the end of semester examination and the overall theory course performance for low engaged students was significantly lower than those in the moderately engaged and highly engaged groups.

4.4.4.5.2 Academic performance in CHEM2911

A one-way ANOVA revealed that there was no significant difference in the end of semester examination score [$F_{2, 57} = 2.789$, $p = 0.070$] but a significant difference in the overall theory course performance among [$F_{2, 57} = 3.662$, $p = 0.032$] the three engagement groups (see Table I.6). A post-hoc Tukey's *t*-test indicated that the mean score for the overall theory course performance for low engaged students was significantly lower than those in the highly engaged group.

4.4.4.5.3 Academic performance in CHEM2915

A one-way ANOVA revealed that there was no significant difference in the end of semester examination score [$F_{2, 17} = 1.436$, $p = 0.265$] and the overall academic performance [$F_{2, 17} = 1.626$, $p = 0.226$] among the three engagement groups.

4.4.4.6 Academic performance at a course level for Group B_2 semester 2

4.4.4.6.1 Academic performance in CHEM2402

A one-way ANOVA revealed that there was a significant difference in the end of semester examination score [$F_{2, 117} = 7.099$, $p = 0.001$] and overall theory course performance [$F_{2, 117} = 10.360$, $p < 0.001$] among the three engagement groups (see Table I.7). A post-hoc Tukey's *t*-test indicated that the mean score for the end of semester examination for low engaged students was significantly lower than those that are highly engaged. Post-hoc Tukey's *t*-test also indicated that the mean score for the overall theory course performance for low engaged students was significantly lower than those in the moderately and highly engaged groups.

4.4.4.6.2 Academic performance in CHEM2912

A one-way ANOVA revealed that there was a significant difference in the end of semester examination score [$F_{2, 40} = 7.039$, $p = 0.002$] and in the overall academic performance [$F_{2, 40} = 8.374$, $p = 0.001$, $d = 0.295$] among the three engagement groups (see Table I.8). A post-hoc comparisons using the Tukey's *t*-test indicated that the mean scores for the end of semester examination and overall theory course performance for highly engaged students was significantly higher than those in the low and moderately engaged groups.

4.4.4.6.3 Academic performance in CHEM2916

A one-way ANOVA revealed that there was no significant difference in the end of semester examination score [$F_{2, 5} = 1.823$, $p = 0.223$] and the overall academic performance [$F_{2, 8} = 1.559$, $p = 0.268$] between the three engagement groups.

Table 4.15. Engagement pairs showing significant differences in academic performance for Group B_2 according to a one-way ANOVA analyses and post-hoc Tukey's *t*-test results.

	Semester 1			Semester 2	
	End of semester examination	Overall theory course performance		End of semester examination	Overall theory course performance
Cohort	• LE and HE • ME and HE	• LE and HE • ME and HE	Cohort	• LE and HE • ME and HE	• LE and HE • ME and HE
CHEM2401	• LE and ME • LE and HE	• LE and ME • LE and HE	CHEM2402	• LE and HE	• LE and HE • LE and ME
CHEM2911	• NS	• LE and HE	CHEM2912	• LE and HE • ME and HE	• LE and HE • ME and HE
CHEM2915	• NS	• NS	CHEM2916	• NS	• NS

Note. NS = no significance, LE = low engagement, ME = moderate engagement and HE = high engagement.

4.4.5 Comparison across Group B_1 and Group B_2

Academic performance across the engagement groups was compared using students' overall course performance in the theory component. This academic measure was used instead of the end of semester examination performance as it contributed to 85% of the final course grade and provides a holistic understanding on how engagement with the pre-learning material can affect academic performance

4.4.5.1 Comparison of overall theory course performance across Group B_1 and Group B_2

For Group B_1 and Group B_2, similar trends were observed in semester 1 for the overall theory course performance of the three engagement groups across each of the chemistry courses (see Table 4.16). However, for Group B_1 and Group B_2 different trends were observed in semester 2 for the overall theory course performance of the three engagement groups for the CHEM2402 and CHEM2912 chemistry courses. Section 4.4.5.2 will further explore the academic performance of students in each of the engagement groups across the various courses.

Table 4.16. Comparison of overall theory course performance across engagement groups for Group B_1 and Group B_2**.**

	Group B_1			Group B_2		
Semester 1	*n*	M	SD	*n*	M	SD
CHEM2401	172	41.61	13.44	155	46.36	12.94
CHEM2911	81	54.03	10.74	60	55.80	9.23
CHEM2915	9	64.37	6.07	20	65.57	4.58
Semester 2	*n*	M	SD	*n*	M	SD
CHEM2402	97	44.47	13.15	120	41.33	13.68
CHEM2912	76	57.22	13.89	43	53.78	10.25
CHEM2916	6	41.50	16.84	11	67.44	5.08

Note. M = Mean, SD = standard deviation.

4.4.5.2 Comparison of overall theory course performance per engagement group across Group B_1 and Group B_2.

4.4.5.2.1 Overall theory course performance in Group B_1

A one way-ANOVA revealed that there were significant differences in the overall theory course performance between the low engaged students [$F_{2, 85} = 13.546$, $p < 0.0001$], moderately engaged students [$F_{2, 84} = 21.795$, $p < 0.0001$] and highly engaged students [$F_{2, 84} = 7.425$, $p < 0.001$] for semester 1 (see Figure 4.3 and Table 4.17). A post-hoc Tukey's *t*-test indicated that for the low engaged students the mean score for the overall theory course performance for students in CHEM2401 was significantly lower than those that are in CHEM2911 and CHEM2915. For the moderately engaged students, a significant difference in the mean score for the overall theory course performance was observed between all three chemistry courses. A post-hoc Tukey's *t*-test was not performed for the highly engaged students as one group had fewer than two cases. Instead, an independent samples *t*-test revealed that highly engaged students in CHEM2911 performed significantly higher in the overall theory course performance than those in CHEM2401($t_{84} = -3.770$, $p < 0.0001$).

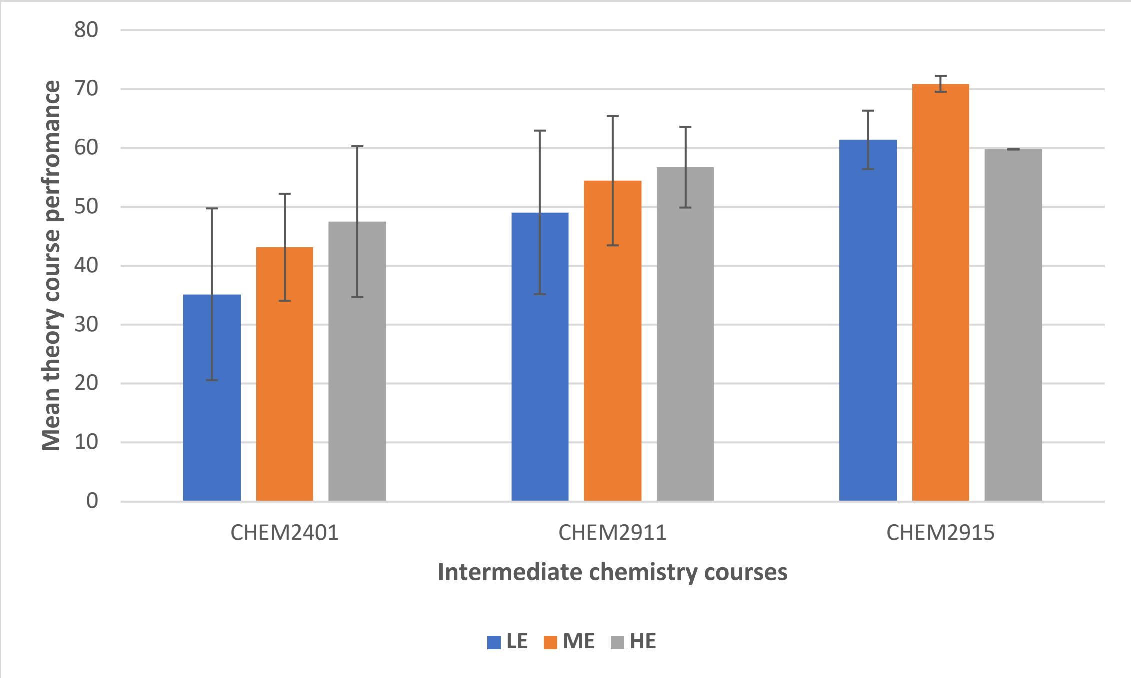

Figure 4.3. Overall theory course performance per engagement groups across all three intermediate chemistry courses: CHEM2401 (n = 172), CHEM2911 (n = 81) and CHEM2915 (n = 9) for Group B_1 in semester 1.

Note. LE = low engagement, ME = moderate engagement, HE = high engagement. Error bars represent the standard error in the mean.

Table 4.17. ANOVA comparisons and post-hoc Tukey's t-test results for the overall theory course performance for students in Group B_1 for semester 1 across the engagement groups.

Low engagement				Tukey's HSD Comparisons		
	n	M	SD	CHEM2401	CHEM2911	CHEM2915
CHEM2401	63	35.18	14.57	-		
CHEM2911	20	49.07	13.88	$p = 0.001$***	-	
CHEM2915	5	61.39	4.95	$p < 0.001$***	$p = 0.195$	-

Moderate engagement				Tukey's HSD Comparisons		
	n	M	SD	CHEM2401	CHEM2911	CHEM2915
CHEM2401	55	43.17	9.07	-		
CHEM2911	29	54.45	10.97	$p < 0.001$***	-	
CHEM2915	3	70.88	1.34	$p < 0.001$***	$p = 0.017$*	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, *$p < 0.05$, ***$p < 0.001$

A one way-ANOVA revealed that there were significant differences in the overall theory course performance between the low engaged students [$F_{2, 60} = 4.056$, $p = 0.022$], moderately engaged students [$F_{2, 54} = 16.714$, $p < 0.0001$] and highly engaged students [$F_{2, 56} = 3.596$, $p = 0.034$] for semester 2 (see Figure 4.4 and Table 4.18). A post-hoc Tukey's *t*-test indicated that for the low engaged students the mean score for the overall theory course performance for students in CHEM2402 was significantly lower than those in CHEM2912. For the moderately engaged students, the mean score for the overall theory course performance was significantly higher for students in CHEM2912 compared to those that are in CHEM2402 and CHEM2916. A post-hoc Tukey's *t*-test was not performed for the highly engaged students as one group had fewer than two cases. Instead, an independent samples *t*-test revealed no significant difference in the overall theory course performance for highly engaged students in CHEM2402 and CHEM2912 ($t_{84} = -3.770$, $p < 0.0001$).

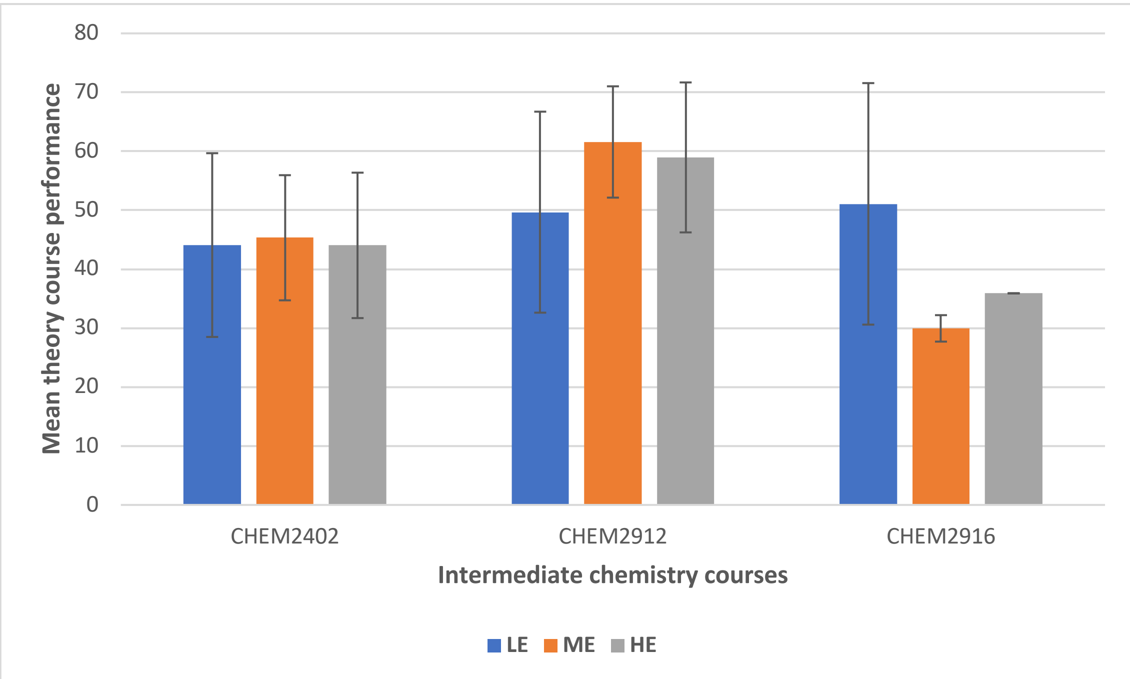

Figure 4.4. Overall theory course performance per engagement groups across all three intermediate chemistry courses: CHEM2402 (*n* = 97), CHEM2912 (*n* = 76) and CHEM2916 (*n* = 6) for Group B_1 in semester 2.

Note. LE = low engagement, ME = moderate engagement, HE = high engagement. Error bars represent the standard error of the mean.

Table 4.18. ANOVA comparisons and post-hoc Tukey's *t*-test results for the overall theory course performance for students in Group B_1 for semester 2 across the engagement groups.

Low engagement				Tukey's HSD Comparisons		
	n	M	SD	CHEM2402	CHEM2912	CHEM2916
CHEM2402	39	39.91	10.55			
CHEM2912	21	49.67	17.05	p = 0.026*	-	
CHEM2916	3	51.08	20.49	p = 0.356	p = 0.984	-

Moderate engagement				Tukey's HSD Comparisons		
	n	M	SD	CHEM2402	CHEM2912	CHEM2916
CHEM2402	31	43.65	16.62	-		
CHEM2912	24	61.58	9.44	p < 0.001***	-	
CHEM2916	2	29.95	2.25	p = 0.299	p = 0.003**	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, *$p < 0.05$, ** $p < 0.01$, ***$p < 0.001$.

4.4.5.2.2 Overall theory course performance in Group B_2

A one way-ANOVA revealed that there were significant differences in the overall theory course performance between the low engaged students [$F_{2, 76}$ = 54.290, p < 0.0001] and highly engaged students [$F_{2, 72}$ = 7.366, p = 0.001] but no significant differences were observed for the moderately engaged students [$F_{2, 78}$ = 3.953, p = 0.023]for semester 1 (see Figure 4.5 and Table 4.19). A post-hoc Tukey's *t*-test indicated that for the low engaged students a significant difference in the mean score for the overall theory course performance was observed between all three chemistry courses. For the highly engaged students, the mean score for the overall theory course performance was significantly higher for students in CHEM2401 compared to those that are in CHEM2911 and CHEM2915.

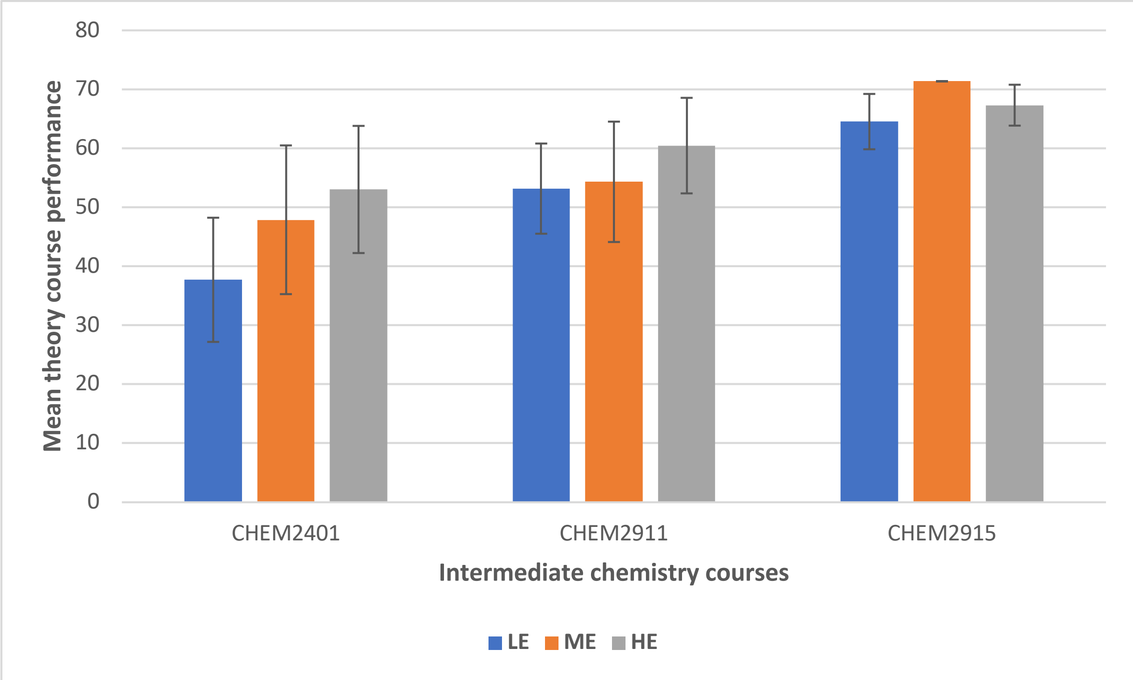

Figure 4.5. Overall theory course performance per engagement groups across all three intermediate chemistry courses: CHEM2401 (n = 155), CHEM2911 (n = 60) and CHEM2915 (n = 20) for Group B_1 in semester 1.

Note. LE = low engagement, ME = moderate engagement, HE = high engagement. Error bars represent the standard error in the mean.

Table 4.19. ANOVA comparisons and post-hoc Tukey's *t*-test results for the overall theory course performance for students in Group B_2 for semester 1 across the engagement groups.

Low engagement				Tukey's HSD Comparisons		
	n	M	SD	CHEM2401	CHEM2911	CHEM2915
CHEM2401	49	37.71	10.53	-		
CHEM2911	19	52.17	7.65	$p < 0.001$***	-	
CHEM2915	14	64.53	4.69	$p < 0.001$***	$p < 0.001$***	-

High engagement				Tukey's HSD Comparisons		
	n	M	SD	CHEM2401	CHEM2911	CHEM2915
CHEM2401	51	53.03	10.79	-		
CHEM2911	18	60.46	8.10	$p = 0.021$*	-	
CHEM2915	5	67.32	3.47	$p = 0.008$**	$p = 0.363$	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, *$p < 0.05$, ** $p < 0.01$, ***$p < 0.001$.

A one way-ANOVA revealed that there were significant differences in the overall theory course performance between the low engaged students [$F_{2, 56} = 23.696$, $p < 0.0001$], moderately engaged students [$F_{2, 58} = 3.774$, $p = 0.029$] and highly engaged students [$F_{2, 51} = 20.427$, $p < 0.0001$] for semester 2 (see Figure 4.6 and Table 4.20). A post-hoc Tukey's *t*-test indicated that for the low engaged students a significant difference in the mean score for the overall theory course performance was observed between all three chemistry courses. A post-hoc Tukey's *t*-test was not performed for the moderately engaged students as one group had fewer than two cases. Instead, an independent samples *t*-test revealed no significant difference in the overall theory course performance for highly engaged students in CHEM2402 and CHEM2912 ($t_{57} = -1.474$, $p = 0.146$). For the highly engaged students, the mean score for the overall theory course performance was significantly lower for students in CHEM2402 compared to those that are in CHEM2912 and CHEM2916.

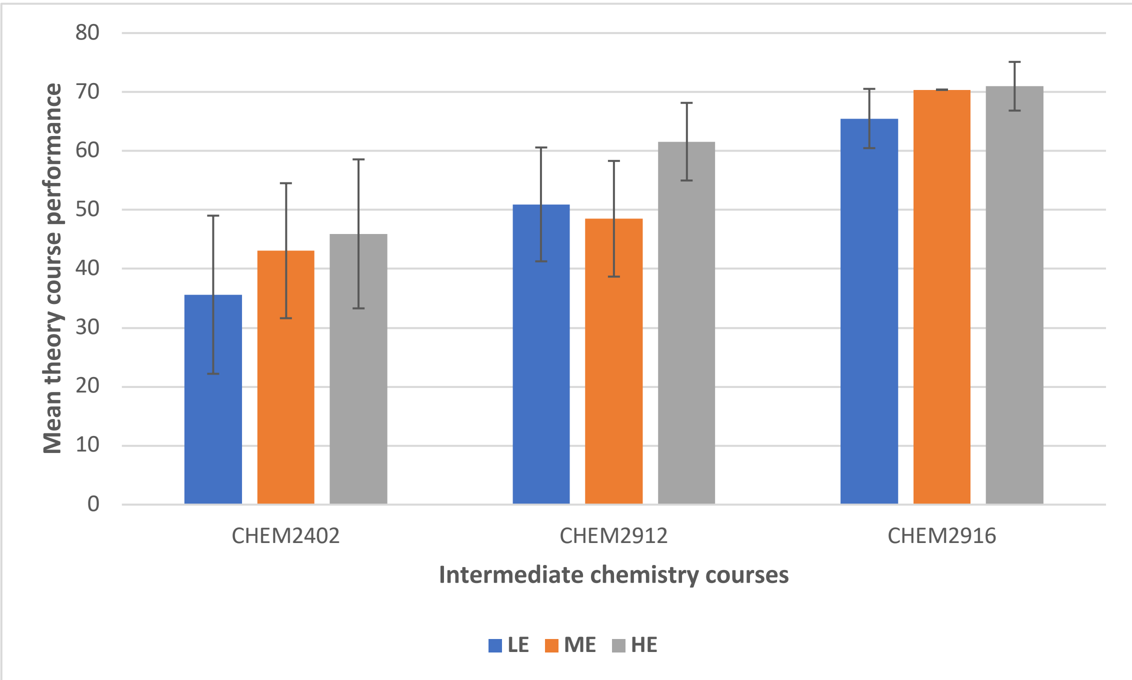

Figure 4.6. Overall theory course performance per engagement groups across all three intermediate chemistry courses: CHEM2402 (*n* = 120), CHEM2912 (*n* = 43) and CHEM2916 (*n* = 11) for Group B_2 in semester 2.

Table 4.20. ANOVA comparisons and post-hoc Tukey's t-test results for the overall theory course performance for students in Group B_2 for semester 2 across the engagement groups.

Low engagement				Tukey's HSD Comparisons		
	n	M	SD	CHEM2402	CHEM2912	CHEM2916
CHEM2402	34	35.61	13.41			
CHEM2912	18	50.94	9.66	$p < 0.001$***	-	
CHEM2916	7	65.50	5.03	$p < 0.001$***	$p = 0.019$*	-

High engagement				Tukey's HSD Comparisons		
	n	M	SD	CHEM2402	CHEM2912	CHEM2916
CHEM2402	37	47.91	9.26	-		
CHEM2912	14	61.58	6.59	$p < 0.001$***	-	
CHEM2916	3	70.98	4.13	$p < 0.001$***	$p = 0.201$	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, *$p < 0.05$, ** $p < 0.01$, ***$p < 0.001$.

4.4.5.3 Comparison of sub-groups of students

The academic performance of a sub-group of students that had completed both semester 1 and semester 2 intermediate chemistry courses in the same academic year was analysed for each of the two different cohorts from Group B_1 and Group B_2. The academic measure used was the end of semester examination performance and data were compared on a cohort and course level. To compare changes in academic performance across semesters, students' engagement group for each semester was recorded. For example, the academic performance for low engaged students in semester 1 was compared to how they performed in semester 2 based on their identified engagement group for semester 2 (low, moderate, and high).

Initial analysis was made by comparing students' academic performance in the end of semester 1 examination and unmodified end of semester 2 examination. Student outcomes across the two semesters are different even though the course activities and end of semester examinations are designed to be equivalent. Historically, in semester 2 the failure rates are higher, as can be seen by the unmodified end of semester 2 examination performance. To allow for the comparison across both semesters, the end of semester examination results for semester 2 were modified based on a common ratio for the sub-group of students that had completed the intermediate chemistry courses for both semesters.

To calculate the modified end of semester examination results, *d* was calculated:

$$d = \frac{M_1}{M_2} \tag{4.1}$$

Where M_1 is the mean value of the end of semester examination for semester 1 and M_2 is the mean value of the end of semester examination for semester 2. The unmodified semester 2 results were then multiplied by *d* to generate the modified end of semester examination results for semester 2.

4.4.5.3.1 Comparison of sub-groups of students in Group B_1

The overall cohort data showed that there were no significant differences in the end of semester examination performance between the two semesters (see Table 4.21). From the course data, significant differences in the end of semester examination performance were observed between one group in CHEM2401/CHEM2402 and one group in CHEM2911/CHEM2912 (see Table 4.22). For these two pairs of groups, detailed patterns for their online behavioural engagement are presented to identify which other parameters contributed to the observed changes in academic performance (See Table 4.23 and Table 4.24). It should be noted that fewer inferences were drawn for the CHEM2915/CHEM2916 group due to the relatively small sample size and the process of modifying the end of semester 2 examination results has been reported for completion.

Table 4.21. Course comparison of end of semester examination for the sub-group of students that completed both pairs of intermediate chemistry courses in sequence in Group B_1.

Chemistry course pairs	Semester 1			Unmodified semester 2		Modified semester 2		Significance unmodified	Significance modified
	n	M_1	SD_1	M_2	SD_2	M_2'	SD_2'		
Overall cohort	143	61.87	17.42	63.74	23.74	61.87	16.91	$p = 0.130$	$p = 0.500$
CHEM2401/CHEM2402	76	53.47	15.99	54.68	21.06	53.47	19.76	$p = 0.272$	$p = 0.499$
CHEM2911/CHEM2912	62	70.24	13.51	76.16	20.26	70.24	18.68	$p = 0.007$**	$p = 0.499$
CHEM2915/CHEM2916	5	85.70	11.13	47.50	34.10	65.44	31.71	$p = 0.041$*	$p = 0.139$

Note. M_1 = semester 1 mean, SD_1 = semester 1 standard deviation, M_2 = unmodified semester 2 mean, SD_2 = unmodified semester 2 standard deviation, M_2' = modified semester 2 mean, SD_2' = modified semester 2, standard deviation, *$p < 0.05$, **$p < 0.01$.

Table 4.22. Course comparison per engagement group for the end of semester examination for the sub-group of students that completed both pairs of intermediate chemistry courses across semesters 1 and 2 in Group B_1.

	Semester 1				Semester 1			Semester 2 unmodified		Semester 2 modified		Significance unmodified	Significance modified
CHEM2401	*n*	M_1	SD_1	CHEM2402	*n*	$M_1^{\wedge}$	$SD_1^{\wedge}$	M_2	SD_2	M_2'	SD_2'	*p* value	*p* value
LE	21	45.88	12.05	LE	18	45.67	9.97	50.73	9.49	49.61	9.28	$p = 0.015$*	$p = 0.040$*
				ME	3	47.17	24.58	51.29	31.73	50.16	31.03	$p = 0.340$	$p = 0.054$
				HE	0	-	-	-	-	-	-	-	-
ME	28	50.32	14.02	LE	10	49.80	13.03	51.55	18.00	50.29	17.56	$p = 0.320$	$p = 0.447$
				ME	11	50	22.24	50.06	22.24	48.83	4	$p = 0.496$	$p = 0.412$
				HE	7	51.57	11.41	59.05	13.71	57.61	9.76	$p = 0.146$	$p = 0.190$
HE	27	62.65	16.34	LE	4	66.38	12.61	36.28	42.81	35.48	41.87	$p = 0.123$	$p = 0.094$
				ME	9	57.78	17.92	55.71	28.71	54.48	28.08	$p = 0.386$	$p = 0.318$
				HE	14	64.71	16.57	68.78	16.86	67.25	16.49	$p = 0.067$	$p = 0.165$
CHEM2911	*n*	M_1	SD_1	CHEM2912	*n*	M_1	SD_1	M_2	SD_2	M_2'	SD_2'	*p* value	*p* value
LE	13	56.29	8.47	LE	6	66.42	10.57	70.46	10.22	64.98	9.42	$p = 0.199$	$p = 0.374$
				ME	7	74.57	11.86	84.79	16.28	78.20	15.02	$p = 0.021$*	$p = 0.180$
				HE	0	-	-	-	-	-	-	-	-
ME	21	54.67	10.13	LE	8	60.69	25.43	62.98	24.96	58.09	23.02	$p = 0.414$	$p = 0.399$
				ME	7	74.43	9.75	80.29	16.30	74.05	15.04	$p = 0.192$	$p = 0.475$
				HE	6	67.58	11.15	81.21	14.03	74.90	12.94	$p = 0.005$*	$p = 0.035$*
HE	28	57.34	6.48	LE	4	73	12.21	61.88	32.02	57.07	38.75	$p = 0.310$	$p = 0.228$
				ME	7	73.14	8.85	79.05	19.05	72.91	12.29	$p = 0.132$	$p = 0.480$
				HE	6	71.68	10.79	79.51	19.05	73.33	18.12	$p = 0.033$*	$p = 0.329$

Note. M_1 = semester 1 mean, SD_1 = semester 1 standard deviation, $M_1^{\wedge}$ = semester 1 mean of specific engagement group, $SD_1^{\wedge}$ = semester 1 standard deviation of specific engagement group, M_2 = unmodified semester 2 mean, SD_2 = unmodified semester 2, standard deviation, M_2' = modified semester 2 mean, SD_2' = modified semester 2 standard deviation. LE = low engagement, ME = moderate engagement, HE = high engagement, *$p < 0.05$, **$p < 0.01$.

The results revealed a significance increase in the end of semester examination performance when the sub-group of low engaged students in CHEM2401 remained low engaged in CHEM2402 (see Table 4.22). The sub-group of low engaged students in semester 2 improved on three of the five engagement index parameters, specifically *mtquiz,* time spent on quiz and *afquiz* time spend on feedback, with some improvements noted in *asquiz* their average quiz score (see Table 4.23).

Table 4.23. Changes in engagement index parameters for a sub-group of students in CHEM2401/CHEM2402 for Group B_1 across both semesters.

	Mtquiz [/20]		Asquiz [/20]		Afquiz [/20]		Engagement index score [EI/100]	
Student	S_1	S_2	S_1	S_2	S_1	S_2	EI S_1	EI S_2
A	9	11	1	4	10	7	34	45
B	6	8	5	12	12	11	34	45
C	4	5	5	10	5	8	29	44
D	1	3	5	7	1	7	28	42
E	6	10	3	6	3	10	26	42
F	11	7	1	3	2	4	25	37
G	7	6	0	7	7	9	25	36
H	10	2	0	1	5	13	24	33
I	5	4	3	3	5	7	24	30
J	10	5	3	1	2	4	24	29
K	1	6	7	5	0	1	23	28
L	5	2	2	6	6	1	18	27
M	4	2	2	6	1	0	17	25
N	1	5	2	5	0	5	16	25
O	1	3	1	5	0	6	14	23
P	2	1	3	1	1	2	11	22
Q	9	2	6	2	1	3	8	22
R	0	2	0	4	0	3	6	17

Note. S_1 = semester 1, S_2 = semester 2. mtquiz = median time spent per attempted quiz, asquiz = average score of the total number of attempted quizzes, and afquiz = average time spent on feedback of the total number of attempted quizzes. EI S_1 = semester 1 engagement index score, EI S_2 = semester 2 engagement index score.

The results revealed a significance increase in the end of semester examination performance when the sub-group of moderately engaged students in CHEM2911 changed to highly engaged in CHEM2912 (see Table 4.22). The sub-group of highly engaged students in semester 2 improved on three of the five engagement index parameters, specifically *mtquiz,* time spent on quiz and *afquiz* time spend on feedback, with some improvements noted in *asquiz* their average quiz score (see Table 4.24).

Table 4.24. Changes in engagement index parameters for a sub-group of students in CHEM2911/CHEM2912 for Group B_1 across both semesters.

	Mtquiz [/20]		Asquiz [/20]		Afquiz [/20]		Engagement index score [EI/100]	
Student	S_1	S_2	S_1	S_2	S_1	S_2	EI S_1	EI S_2
A	6	17	15	9	8	17	49	76
B	4	12	12	14	13	14	49	68
C	11	10	10	15	17	9	48	65
D	10	7	5	19	8	12	38	63
E	9	15	3	12	5	12	37	63
F	8	13	7	13	5	5	35	59

Note. S_1 = semester 1, S_2 = semester 2. mtquiz = median time spent per attempted quiz, asquiz = average score of the total number of attempted quizzes, and afquiz = average time spent on feedback of the total number of attempted quizzes. EI S_1 = semester 1 engagement index score, EI S_2 = semester 2 engagement index score.

4.4.5.3.2 Comparison of sub-groups of students in Group B_2

The overall cohort data showed that there were no significant differences in the end of semester examination performance between the two semesters (see Table 4.25). From the course data, significant differences in the end of semester examination performance were observed between one group in the CHEM2401/CHEM2402, one group in the CHEM2911/CHEM2912 and one group in CHEM2915/CHEM2916 (see Table 4.26 and Table 4.27). For these three pairs of groups, detailed patterns for their online behavioural engagement are presented to identify which other parameters contributed to the observed changes in academic performance (See Table 4.28 to Table 4.30). It should be noted that fewer inferences were drawn for the CHEM2915/CHEM2916 group due to the relatively small sample size.

Table 4.25. Course comparison of end of semester examination for the sub-group of students that completed both pairs of intermediate chemistry courses in sequence in Group B_2.

Chemistry course pairs	Semester 1			Unmodified semester 2		Modified semester 2		Significance unmodified	Significance modified
	n	M_1	SD_1	M_2	SD_2	M_2’	SD_2’		
Overall cohort	124	64.83	18.80	61.07	20.65	64.83	21.93	$p < 0.001$***	$p = 0.499$
CHEM2401/CHEM2402	73	57.84	18.90	52.45	19.21	57.79	21.08	$p < 0.001$***	$p = 0.487$
CHEM2911/CHEM2912	41	71.92	13.15	69.62	15.29	71.87	15.69	$p = 0.122$	$p = 0.489$
CHEM2915/CHEM2916	10	86.76	5.91	88.90	6.42	86.76	6.27	$p = 0.123$	$p = 0.499$

Note. M_1 = semester 1 mean, SD_1 = semester 1 standard deviation, M_2 = unmodified semester 2 mean, SD_2 = unmodified semester 2 standard deviation, M_2’ = semester 2 mean, SD_2’ = modified semester 2 standard deviation, ***$p < 0.001$.

Table 4.26. Course comparison per engagement group for the end of semester examination for the sub-group of students that completed both pairs of CHEM2401/CHEM2402 and CHEM2912/CHEM2912 across semesters 1 and 2 in Group B_2.

	Semester 1					Semester 1		Semester 2 unmodified		Semester 2 modified		Significance unmodified	Significance modified
CHEM2401	*n*	M_1	SD_1	CHEM2402	*n*	$M_1^{\wedge}$	$SD_1^{\wedge}$	M_2	SD_2	M_2'	SD_2'	*p* value	*p* value
				LE	10	46.18	12.54	40.50	16.98	44.66	18.72	$p = 0.168$	$p = 0.403$
LE	19	46.18	12.54	ME	9	51.52	11.57	49.50	10.94	54.59	12.07	$p = 0.204$	$p = 0.121$
				HE	0	-	-	- -	-	-	-	-	-
				LE	9	58.96	23	47.28	23.73	52.14	26.17	$p = 0.017$*	$p = 0.196$
ME	30	50.32	14.02	ME	14	58.36	23.53	54.39	24.45	59.98	26.97	$p = 0.061$	$p = 0.278$
				HE	7	52.57	19.14	49.93	20.60	55.06	22.71	$p = 0.223$	$p = 0.258$
				LE	1	67.29	-	41.5	-	-	-	-	-
HE	24	62.65	16.34	ME	10	60.69	19.28	56.35	15.78	61.78	16.44	$p = 0.151$	$p = 0.393$
				HE	13	69.77	14.10	64.38	12.90	71	14.22	$p = 0.039$*	$p < 0.001$***

CHEM2911	*n*	M_1	SD_1	CHEM2912	*n*	M_1	SD_1	M_2	SD_2	M_2'	SD_2'	*p* value	*p* value
				LE	11	67.80	10.08	68.22	14.65	70.48	15.14	$p = 0.464$	$p = 0.293$
LE	14	68.19	8.91	ME	2	68.34	0.23	58.75	0.35	60.69	0.37	$p = 0.014$*	$p = 0.017$*
				HE	1	72.24	-	68.5	-	- -	-	- -	-
				LE	7	75.59	13.14	64.93	15.76	67.07	16.28	$p = 0.030$*	$p = 0.061$
ME	13	68.45	15.51	ME	5	57.12	14.19	58.1	13.38	60.02	16.92	$p = 0.452$	$p = 0.367$
				HE	1	75.18	-	76	-	-	-	-	-
				LE	1	71.89	-	62	-	-	-	-	-
HE	14	78.87	12.32	ME	2	66.86	10.96	59.5	7.78	61.47	8.04	$p = 0.339$	$p = 0.379$
				HE	11	81.69	11.94	83.27	10.72	85.82	10.77	$p = 0.203$	$p = 0.023$

Note. M_1 = semester 1 mean, SD_1 = semester 1 standard deviation, $M_1^{\wedge}$ = semester 1 specific engagement group mean, $SD_1^{\wedge}$ = semester 1 specific engagement group standard deviation, M_2 = unmodified semester 2, mean, SD_2 = unmodified semester 2 standard deviation, M_2' = modified semester 2 mean, SD_2' = modified semester 2 standard deviation. LE = low engagement, ME = moderate engagement, HE= high engagement, * $p < 0.05$, *** $p < 0.001$.

Table 4.27. Course comparison per engagement group for the end of semester examination for the sub-group of students that completed both pairs of CHEM2915/CHEM2916 across semesters 1 and 2 in Group B_2.

	Semester 1					Semester 1		Semester 2 unmodified		Semester 2 modified		Significance unmodified	Significance modified
CHEM2915	*n*	M_1	SD_1	CHEM2916	*n*	$M_1^{\wedge}$	$SD_1^{\wedge}$	M_2	SD_2	M_2'	SD_2'	*p* value	*p* value
				LE	4	83.51	5.38	86.67	6.60	83.08	6.06	$p = 0.234$	$p = 0.465$
HE	6	46.18	12.54	ME	1	85.29	-	49.5	-	54.59	-	$p = 0.204$	$p = 0.121$
				HE	1	88.39	-	-	-	-	-	-	-
				LE	2	94.67	3.22	91.5	8.49	89.30	8.28	$p = 0.275$	$p = 0.187$
HE	4	62.65	16.34	ME	0	-	-	-	-	-	-	-	-
				HE	2	85.62	8.17	93.25	6.13	91	5.94	$p = 0.039$*	$p < 0.001$***

Note. M_1 = semester 1 mean, SD_1 = semester 1 standard deviation, $M_1^{\wedge}$ = semester 1 specific engagement group mean, $SD_1^{\wedge}$ = semester 1 specific engagement group standard deviation, M_2 = unmodified semester 2, mean, SD_2 = unmodified semester 2 standard deviation, M_2' = modified semester 2 mean, SD_2' = modified semester 2 standard deviation. LE = low engagement, ME = moderate engagement, HE= high engagement, * $p< 0.05$, *** $p< 0.001$.

The results revealed a significance increase in the end of semester examination performance when the sub-group of highly engaged students in CHEM2401 remained highly engaged in CHEM2402 (see Table 4.26). The sub-group of highly engaged students in semester 2 improved on three of the five engagement index parameters, specifically *mtquiz,* time spent on quiz and *afquiz* time spend on feedback, but a decrease was noted in *asquiz* their average quiz score (see Table 4.28).

Table 4.28. Changes in engagement index parameters for a sub-group of students in CHEM2401/CHEM2402 for Group B_2 across both semesters.

	Mtquiz [/20]		Asquiz [/20]		Afquiz [/20]		Engagement index score [EI/100]	
Student	S_1	S_2	S_1	S_2	S_1	S_2	EI S_1	EI S_2
A	20	18	20	4	20	15	89	89
B	15	19	20	12	14	20	79	87
C	13	18	15	10	17	15	77	86
D	17	19	16	7	15	17	73	75
E	16	17	18	6	13	6	72	72
F	20	12	17	3	18	14	69	69
G	17	16	19	7	14	12	68	68
H	18	12	17	1	10	16	63	63
I	18	17	12	3	8	9	62	63
J	14	16	10	1	17	12	59	63
K	10	12	16	5	10	12	58	60
L	11	10	14	6	9	11	55	58
M	13	12	12	6	10	9	55	58

Note. S_1 = semester 1, S_2 = semester 2. mtquiz = median time spent per attempted quiz, asquiz = average score of the total number of attempted quizzes, and afquiz = average time spent on feedback of the total number of attempted quizzes. EI S_1 = semester 1 engagement index score, EI S_2 = semester 2 engagement index score.

The results revealed a significance decrease in the end of semester examination performance when the sub-group of low engaged students in CHEM2911 changed to moderately engaged in CHEM2912 (see Table 4.26). The sub-group of moderately engaged students in semester 2 improved on one of the five engagement index parameters, specifically *afquiz* time spend on feedback (see Table 4.29).

Table 4.29. Changes in engagement index parameters for a sub-group of students in CHEM2911/CHEM2912 for Group B_2 across both semesters.

	Mtquiz [/20]		Asquiz [/20]		Afquiz [/20]		Engagement index score [EI/100]	
Student	S_1	S_2	S_1	S_2	S_1	S_2	EI S_1	EI S_2
A	5	7	8	8	7	12	35	47
B	6	6	9	7	5	8	34	46

Note. S_1 = semester 1, S_2 = semester 2. mtquiz = median time spent per attempted quiz, asquiz = average score of the total number of attempted quizzes, and afquiz = average time spent on feedback of the total number of attempted quizzes. EI S_1 = semester 1 engagement index score, EI S_2 = semester 2 engagement index score.

The results revealed a significance increase in the end of semester examination performance when the sub-group of highly engaged students in CHEM2915 remained highly engaged in CHEM2916 (see Table 4.26). The sub-group of highly engaged students in semester 2 had a lower score on one of the five engagement index parameters, specifically *afquiz* time spend on feedback (see Table 4.30).

Table 4.30. Changes in engagement index parameters for a sub-group. of students in CHEM2915/CHEM2916 for Group B_2 across both semesters.

	Mtquiz [/20]		Asquiz [/20]		Afquiz [/20]		Engagement index score [EI/100]	
Student	S_1	S_2	S_1	S_2	S_1	S_2	EI S_1	EI S_2
A	16	16	15	12	12	9	59	64
B	15	10	12	13	12	8	56	62

Note. S_1 = semester 1, S_2 = semester 2. mtquiz = median time spent per attempted quiz, asquiz = average score of the total number of attempted quizzes, and afquiz = average time spent on feedback of the total number of attempted quizzes. EI S_1 = semester 1 engagement index score, EI S_2 = semester 2 engagement index score.

4.4.5.4 Level of engagement and academic performance

To further analyse engagement, the percentage of students in each merit grade distribution was compared across the three level of engagements (see Figures 4.7 to Figure 4.10). Similar trends were observed across Group B_1 and Group B_2, with the percentage of students failing decreased with higher levels of engagement and the percentage of students achieving a Distinction or High Distinction grade increased with higher levels of engagement.

The data for Group B_1 revealed that 18% of the students who failed in semester 1 were in the low engaged group, compared to 7% in the highly engaged group (see Figure 4.7). Five percent of low engaged students achieved a Distinction or High Distinction compared to 8% in the highly engaged group (see Figure 4.7).

The data for Group B_1 revealed that 14% of the students who failed in semester 2 were in the low engaged group, compared to 4% in the highly engaged group (see Figure 4.8). Six percent of low engaged students achieved a Distinction or High Distinction compared to 16% in the highly engaged group (see Figure 4.8).

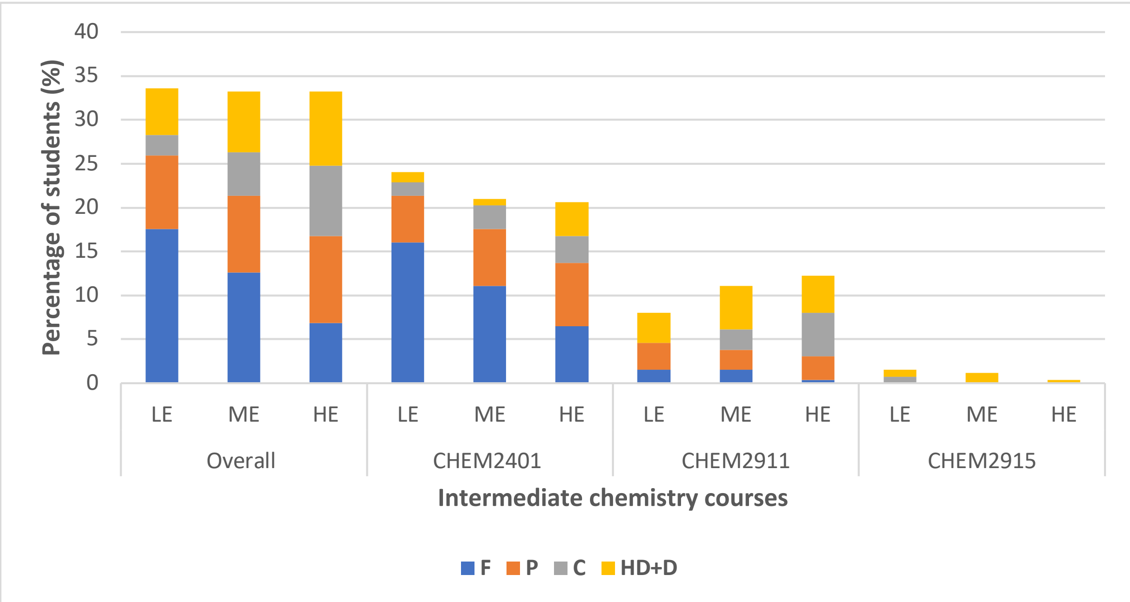

Figure 4.7. Comparison of grade distribution across levels of engagement for all three intermediate chemistry courses: Overall (n = 262), CHEM2401 (n = 172), CHEM2911 (n = 81) and CHEM2915 (n = 9) for Group B_1 in semester 1.

Note. LE = low engagement, ME = moderate engagement, HE = high engagement. HD = high distinction (>85), D = distinction (75-84), C = credit (65-74), P = pass (50-64), F = fail (< 50).

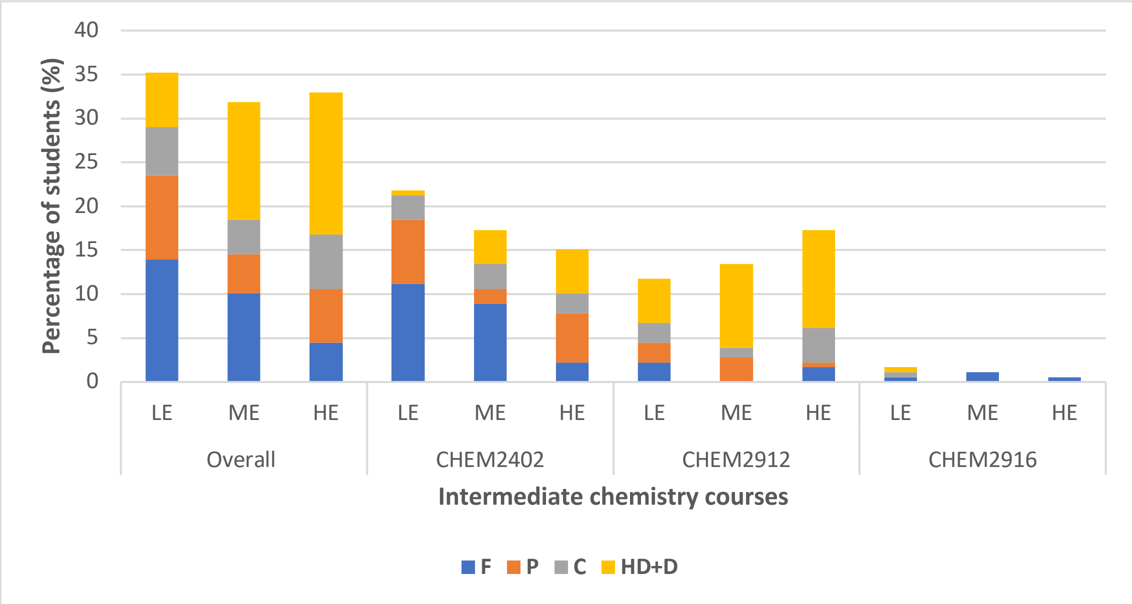

Figure 4.8. Comparison of grade distribution across levels of engagement for all three intermediate chemistry courses: Overall (*n* = 179), CHEM2402 (*n* = 97), CHEM2912 (*n* = 76) and CHEM2916 (*n* = 6) for Group B_1 in semester 2.

Note. LE = low engagement, ME = moderate engagement, HE = high engagement. HD = high distinction (>85), D = distinction (75-84), C = credit (65-74), P = pass (50-64), F = fail (< 50).

The data for Group B_2 revealed that 13% of the students who failed in semester 1 were in the low engaged group, compared to 5% in the highly engaged group (see Figure 4.9). Six percent of low engaged students achieved a Distinction or High Distinction, compared to 16% in the highly engaged group (see Figure 4.9).

The data for Group B_2 revealed that 15% of the students who failed in semester 2 were in the low engaged group, compared to 8% in the highly engaged group (see Figure 4.10). There was 10% of low engaged students achieved a Distinction or High Distinction, compared to 11% in the highly engaged group (see Figure 4.10).

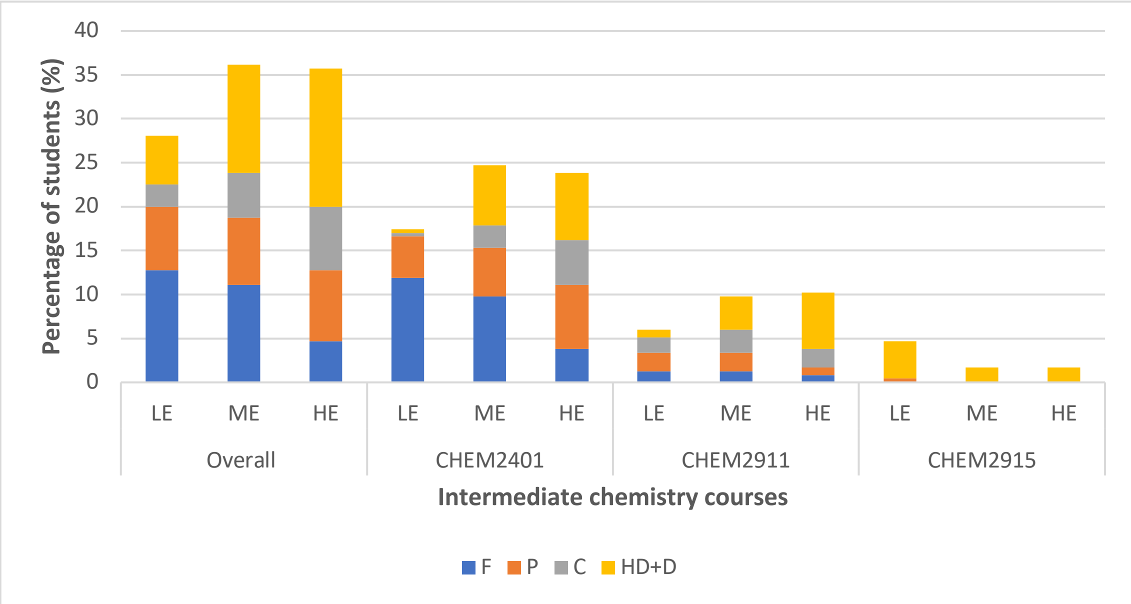

Figure 4.9. Comparison of grade distribution across levels of engagement for all three intermediate chemistry courses: Overall ($n = 235$) CHEM2401 ($n = 155$), CHEM2911 ($n = 60$) and CHEM2915 ($n = 20$) for Group B_2 in semester 1.

Note. LE = low engagement, ME = moderate engagement, HE = high engagement. HD = high distinction (>85), D = distinction (75-84), C = credit (65-74), P = pass (50-64), F = fail (< 50).

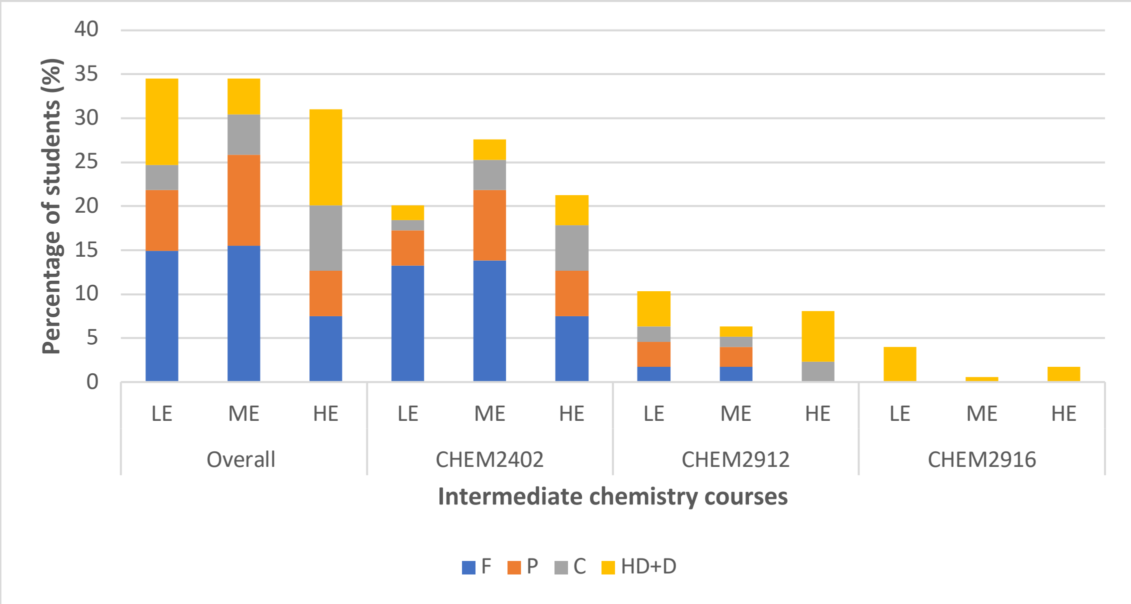

Figure 4.10. Comparison of grade distribution across levels of engagement for all three intermediate chemistry courses: Overall (n =174), CHEM2402 (n = 120), CHEM2912 (n = 43) and CHEM2916 (n = 11) for Group B_2 in semester 2.

Note. LE = low engagement, ME = moderate engagement, HE = high engagement. HD = high distinction (>85), D = distinction (75-84), C = credit (65-74), P = pass (50-64), F = fail (< 50).

On a cohort level, no significant differences were observed in the final course grade performance between failing students across the three levels of engagement for both groups. Similarly, on a cohort level, no significant differences were observed in the final course grade performance between students who achieved a distinction or high distinction merit grade across the three levels of engagement for both groups. For Group B_1, a significant difference was observed in the failed merit grade distribution for CHEM2401, with failure rates decreasing with higher levels of engagement. For Group B_2, significant difference was observed in the failed merit grade distribution for CHEM2402, with failure rates decreasing with higher levels of engagement.

4.5 Discussion

4.5.1 Online behavioural engagement effect on academic performance

This chapter developed an engagement index to measure students' online behavioural engagement levels with the pre-learning materials of a partially flipped learning model. The engagement index was comprised of one parameter related to the pre-learning videos, *nvideo* and four parameters related to the pre-learning quizzes, *mtquiz, asquiz, afquiz, and nquiz.* This chapter contributes to the field as it provides empirical evidence using learning analytics to quantify students' level of engagement (low, moderate, and high) with the online pre-learning materials based on their engagement index score derived from their varying levels of interactions with the five engagement index parameters. The behavioural engagement index proposed also advances current understanding of how varying levels of interaction with the online pre-learning materials may impact academic performance.

Initial analysis comparing cohort level responses for Group B_1 and Group B_2 revealed a significant positive correlation between students' online behavioural engagement score and academic performance. It was observed that higher levels of engagement as measured by students' engagement index score led to significant improvements in their academic performance. More specifically, students that were identified as highly engaged performed significantly better in the end of semester examination and overall theory course performance when compared to those in the moderately and low engaged groups. A preliminary study by Wang (2017) that also developed a behavioural engagement model revealed that engagement with the online problem-solving activities has a significant positive effect on academic achievement in flipped classroom. Although similar findings are reported regarding the effect of students' online behavioural engagement on academic performance, it should be noted that Wang (2017) embedded self-reflection and self-assessment learning activities to facilitate students' online behavioural engagement with the problem-solving activities. The engagement index developed in this thesis focused exclusively on quantifying students' interactions with the online pre-leaning materials. In addition, it reports on how varying degree of interactions with the five parameters related to each of the online pre-learning materials may impact academic performance. Intuitively, it was hypothesised that students who viewed the videos tend to be more engaged with their learning. It was reasonable to assume that more engaged students would spend an adequate amount of time attempting and reading the feedback to achieve a maximum score on the first attempt, or at least with the lowest number of quiz attempts. These results, in conjunction with Wang's (2017) study, support Eichler and Peeples (2016) hypothesis that engagement with the pre-learning materials may be the leading factor behind the observed improvements in academic performance.

Quantifying students' online behavioural engagement using learning analytics complements current findings that rely on traditional self-reported responses collected from students often in the form of questionnaires (Jovanović, et al., 2017). For instance, Lee and Choi (2019) found that students' engagement with the pre-learning materials were positively correlated with final learning outcomes. This relationship was almost twice when compared to the effect of the in-class component on learning outcomes. Another study by Lee et al. (2018) in a general biology and chemistry flipped learning course revealed that students' behavioural engagement had the greatest impact on content/learning related outcomes. As Wang (2019) suggested, behavioural engagement with the pre-learning materials is important in mediating the relationship between engagement during the in-class sessions and achievement. The engagement index has practical implications for future research as pre-learning videos and quizzes are perceived to be critical components in a flipped learning environment and are integral in facilitating learning during the in-class sessions (Lee & Choi, 2019). Therefore, the engagement index provides a more comprehensive understanding of how students 'actually' engaged with the pre-learning materials and to what extent did their online behavioural engagement with the pre-learning materials relate to their academic performance. The engagement index may also be useful in detecting [dis]engaged behaviours in online learning and assist in targeting interventions that are personalised and address students' individual needs. This is particularly valuable as completing the pre-learning materials improves students' preparedness for the content presented during the in-class sessions which can potentially influence their overall learning experience and their academic performance in a flipped learning environment.

Despite these proposed implications, using learning analytics as a measure of behavioural engagement may not be sufficient to provide an adequate understanding of the quality of engagement (Appleton, Christenson, & Furlong, 2008). Since behaviour with the online pre-learning materials varies across students, it may be difficult to determine the amount of engagement needed for quality academic performance (Henrie et al., 2015). However, the behavioural engagement index proposed classified students on a spectrum based on their level of interaction with the pre-learning materials. This can be used as a tool to examine the relationship between student's behavioural engagement and their academic performance.

Chapter 5 will further expand on students' online behavioural engagement by identifying their distinct behavioural patterns with the pre-learning materials which can potentially detect the dominant behavioural pattern(s).

Several findings were observed when comparing the relationship between students' online behavioural engagement and merit grade distribution. Although not significant, a shift in the merit grade distribution was observed on a cohort level, with an overall increase in distinction and high distinction rates and decrease in failure rates with increased levels of engagement. On a course level, a significant decrease in failure rates with increased levels of engagement was observed only in some of the mainstream courses, CHEM2401 in Group B_1 and CHEM2402 in Group B_2. In the remaining courses, despite showing improvements in merit grade distribution with higher levels of engagement, no significant differences were noted. Combined, these results suggest that higher levels of engagement with pre-learning materials may lead to an improvement in academic performance and a reduction in failure rates. It is possible that completing the pre-learning materials improved students' preparedness for the content presented during the in-class sessions which may have influenced their overall learning experience and their academic performance in a flipped learning environment. These findings align with other studies reporting significant improvements in students' grades and reduced withdrawal and failures rates (Bokosmaty et al., 2019; Smallhorn, 2017; Ryan & Reid, 2016; Flynn; 2015; Weaver & Sturtevant, 2015). Although a direct causal link cannot be concluded, various cognitive and personality constructs of learner's characteristics can facilitate, or hinder, their online behavioural engagement with the pre-learning materials (Swan, 2004). Subsequent sections and chapters will explore how proficiency levels, behavioural patterns, learning processes and strategies can influence online behavioural engagement and impact the academic performance of chemistry students across a range of courses (Keskin & Yurdugül, 2019; Lee & Choi, 2019).

4.5.2 Factors that affect the academic performance of students in a flipped learning model

On a cohort level, it was found that students with higher levels of engagement with the pre-learning materials, as quantified by the engagement index, performed significantly better in the end of semester examination and had better overall theory course performance than those less engaged. When comparing the three different course levels; mainstream, advanced and SSP courses in Group B_1 and Group B_2, similar trends were observed amongst the semester 1 courses, whereas different trends were observed amongst the semester 2 courses. While this was the case, general patterns were apparent across both semesters when comparing differences in the academic performance of the specific engagement levels (low, moderate, and high) amongst the three different course levels. The most pronounced statistically significant differences were observed in the academic performance of students in the mainstream courses across the three levels of engagement. Some statistically significant variations were observed in the advanced courses whereas no statistically significant differences were noted for the SSP courses. While the pre-learning materials were not compulsory for the mainstream and advanced courses, it is presumed that the incentive marks associated with the pre-learning quizzes may have encouraged students' engagement. No incentive graded component was awarded for completing the pre-learning materials in the SSP courses and participation was voluntary. It should also be noted that while the overall academic performance of the SSP courses was higher than the remaining courses, the sample size was relatively small for further inferences to be drawn.

The differences observed in students' engagement levels across the three intermediate chemistry courses may be related to students' motivation (Abeysekara & Dawson, 2015). The graded component assigned to the online pre-learning materials in the mainstream and advanced course compared to the SSP may have influenced students' intrinsic motivation through extrinsic means i.e., the incentive mark may have encouraged those students to complete them. This may also be a reason for the relatively small sample size observed in the SSP course, since no summative marks are available for completing the pre-learning quizzes the students may have decided to not complete them. While it is not feasible from the data collected to determine whether students were intrinsically motivated to complete or felt the need to complete them to be rewarded the marks subsequent chapters provide insight into students' perception towards the online pre-learning materials.

The differences in academic performance as measured by the end of semester examination and overall theory course performance across the different engagement levels may have also been influenced by a range of factors including individual learners' related characteristics as well as the instructional design of the pre-learning materials (Jesurasa, Mackenzie, Jordan, & Goyder, 2017; Lee et al., 2018). The observed trends were proposed to be associated with students' proficiency level of chemistry; students in the mainstream courses tend to have a weaker background in chemistry than the advanced and SSP courses. There is some evidence to suggest that the instructional design of the flipped learning model has the potential to reduce cognitive load and lead to higher academic performance (Abeysekera & Dawson, 2015). The pre-learning materials are designed to support students in creating relevant cognitive schemas to reduce the demands imposed on their working memory during the in-class sessions (Mayer & Morena, 2003; Seery & Donnelly, 2012). However, the effectiveness of these instructional designs may depend on the levels of expertise in a particular domain, in this case, students' proficiency levels in chemistry. The direct instructions embedded in the pre-learning material can be highly effective for students with lower proficiency but may have minimal, or even negative consequences, on students with higher proficiency levels (Kalyuga, Ayres, Chandler, & Sweller, 2003). This is referred to as the 'reverse expertise effect' and should be taken into consideration in the instructional design of the flipped learning model to appropriately accommodate for students of varying proficiency levels (Kalyuga et al., 2003). According to the reverse expertise effect (Kalyuga et al., 2003) the pre-learning materials may have provided students in the mainstream course with the needed scaffolding to develop their foundational knowledge prior to attending the in-class sessions. Students in the advanced and SSP courses may not have felt the need to interact with the pre-learning materials as they might already have a thorough understanding of the concepts presented or may not perceive the benefits of the pre-learning materials and its contribution to their learning.

The online pre-learning materials may have practical implications towards student learning as they may reduce the "achievement" gap between students in various chemistry courses. Since all students had access to the same pre-learning materials, more consideration needs to be taken in the design of future pre-learning materials to cater for students with diverse learning backgrounds. This can be achieved by adjusting the level of difficulty of the pre-learning materials. The current design offered students to achieve a mastery of the foundational concepts. Alternatively, a different set of pre-learning materials can be designed for each of the three different chemistry courses instead of all students accessing the same ones, to closely align with students' specific background knowledge of chemistry.

Self-regulated learning has been identified as a key learner-related factor that can influence behavioural engagement and improve academic performance (Kim, So, & Joo, 2021). In a flipped learning environment, students are responsible for developing new or adapting their existing learning strategies to regulate their own learning behaviours (Wang, 2019). However, students generally lack the skills to achieve this and often have underdeveloped self-regulated learning skills which can influence their engagement with the pre-learning materials (Jovanović et al., 2017; Jovanović, Mirriahi, Gašević, Dawson, & Pardo, 2019). To address this, instructional designs need to embed self-regulated learning prompts to help students regulate their learning behaviours (Kim et al., 2021). Although self-regulated learning was not explicitly measured in this thesis, it may be another contributing factor that influenced students' engagement with the pre-learning materials and resulted in the varying differences in academic performance. The study was conducted in the intermediate chemistry courses and most of these students had already been exposed to the flipped learning model in the junior chemistry courses. Therefore, they may have developed some self-regulated learning skills from junior chemistry courses. Further research is warranted to examine the extent students' self-regulated learning skills developed from first to second year and to what extend their learning strategies may have influenced their behavioural engagement and impacted their academic performance. Subsequent chapters will provide further insight regarding students' behavioural patterns and adopted learning process and strategies with the pre-learning materials.

While these findings may be context specific to the discussed chemistry courses, some comparisons can be drawn with other research that has measured the influence of students' academic capability as measured by their graded point average (GPA) on their engagement and their academic performance. Lee et al. (2018) showed that students with mid- and high-GPAs tend to be more engaged with pre-learning material and perform significantly better in educational outcomes when compared to those with lower GPAs. Their results imply that the pre-learning materials may have better supported students with higher levels of schema as identified by their GPAs, when compared to those with lower GPAs. Students with lower GPAs may have lower levels of schema and be least familiar with the course material. These findings, however, differ from this current research study which observed the greatest effect in the courses with students of lower proficiency levels. The findings from this study are, however, somewhat consistent with Cormier and Voisard (2018) who categorised students within the same course according to their academic ability and revealed that "low-achieving" students, as categorised by their academic ability, were more engaged and performed significantly better in the final course grades when compared to "high-achieving" students. However, it was not explicitly identified which component(s) of the flipped model may have contributed to the varying levels of engagement and differences in academic performance. Crimmins and Midkiff (2017) also noted improvements in learning outcomes for all students but those at the lowest academic achievement levels appeared to experience the most gain. While it is possible that within each of the chemistry courses a wide spectrum of students with varying proficiency levels are present, this was beyond the scope of this research study. Instead, the data compared the courses holistically by focusing on how the nature of the student cohort different amongst the courses.

4.5.3 The effect of changes in students' behavioural engagement on academic performance across consecutive semesters

To further examine the relationship between students' online behavioural engagement and their academic performance over time, it was essential to focus on a sub-group of students that had completed the intermediate chemistry courses in both semesters. The cohort data for Group B_1 and Group B_2 showed no significant differences in the end of semester examination performance across both semesters. On a course level, no significant differences were noted when comparing end of semester examination performance across semesters for Group B_1 and Group B_2. Since no differences were observed, it was essential to explore how changes in students' online behavioural engagement, as categorised by the engagement index (low, moderate, and high), across semesters affected their academic performance.

There has been limited evidence examining the effects of a flipped learning environment on short-term and long-term educational learning outcomes (O'Flaherty & Philips, 2015). The positive impacts of a flipped learning environment on educational outcomes have been well documented (O'Flaherty & Philips, 2015). Eichler and Peeples (2016) analysed a large introductory chemistry course and found significant improvement in the GPA of students in the flipped learning environment when compared to a traditional teaching setting. Although it was not feasible to isolate the direct effects of the various components of the flipped learning model: pre-learning and in-class learning activities, it was hypothesized that the online pre-learning material had the greater impact on students' academic performance. This supports the findings previously discussed in this study which showed that higher levels of engagement with the pre-learning materials, as measured by the engagement index, led to improvements in end of semester examination and overall theory course performance. Despite this, the effects varied when comparing students' online behavioural engagement across semesters.

Preliminary research conducted by Hsaio et al. (2019) in an introductory calculus course explores the effects of online learning behaviour on short-term and long-term learning outcomes by conducting a multiple linear regression and multiple correspondence analysis.

Their findings revealed that online behavioural learning does not have a significant impact on short-term outcomes as measured by course performance but has a significant impact on long-term learning outcomes as measured by students GPA at the end of the academic year. Although this study also investigated the relationship between learning behaviour and learning outcomes, the presented findings differed from those of Hsaio et al. (2019) as they focused on examining how changes in students' online behavioural patterns as measured by their engagement group across semesters affected their academic performance.

For Group B_1, a significant increase in academic performance was observed when low engaged students in CHEM2401 remained in the low engaged group in CHEM2402. A significant increase in academic performance was observed when moderately engaged students in CHEM2911 changed to highly engaged in CHEM2912. For Group B_2, a significant decrease in academic performance was observed when highly engaged students in CHEM2401 remained highly engaged in CHEM2402. Also, a significant decrease in academic performance was observed when low engaged students in CHEM2911 changed to moderately engaged in CHEM2912. A statistically significant increase in academic performance, was observed when highly engaged students in CHEM2915 remained highly engaged in CHEM2916.

These results reveal no clear pattern between how changes in students' online behavioural engagement across semesters can affect their academic performance. It was expected that if students remained in the same engagement group across both semesters, they would maintain a similar academic performance. This was the case when comparing the academic performance between CHEM2401 and CHEM2402 in Group B_1 and Group B_2. Moreover, it was expected that if students moved up an engagement group, their academic performance would increase and if they moved down an engagement group, their academic performance would decrease. While this was the case when comparing the academic performance between CHEM2911 and CHEM2912 in Group B_1 it was not the case for CHEM2911 and CHEM2912 in Group B_2. These results suggest the need to examine in more detail which of the engagement index parameters may have contributed to the observed changes.

For Group B_1, the students in semester 2 improved on three of the five parameters, specifically time spent on quiz and time spent on feedback, which led to an improvement in their average quiz score. For Group B_2, changes in academic performance between CHEM2401 and CHEM2402 may be related to a decrease in students' average quiz score as all other parameters remained relatively constant across both semesters. For the remaining courses in Group B_2, it was not possible to draw conclusions on which parameters may have contributed to the observed changes as the sample size was small (n = 2). Further research with a larger sample is warranted to draw comparison between the advanced courses (CHEM2911 and CHEM2912) and the SSP courses (CHEM2915 and CHEM1916) as it can provide valuable insight on how the online behavioural engagement pattern of students with a stronger chemistry proficiency level changes across semesters and as a result affects their academic performance.

Although quantifying students' behavioural engagement is perceived to provide valuable insight on their learning process, it is essential to explore student engagement holistically. Wang (2017) suggests that behavioural engagement only explained around 60% of the variance in the final course grade and that other factors related to course design may influence behavioural engagement. O'Flaherty and Philips (2015) suggest that future research should consider examining engagement as a multi-dimensional construct and explore the relationship between indicators of behavioural, cognitive, and emotional engagement and how these may influence achievement in a flipped learning environment. The following chapters explore other facets of students' online behavioural engagement by examining their displayed behavioural patterns and adopted approach to learning with the online pre-learning materials of a partially flipped learning model.

Chapter 5: Behavioural pattern in the online component of a partially flipped learning model

5.1 Introduction

This chapter investigates patterns in students' learning behaviour with the online component of the partially flipped learning model. It explores the potential relationship between students' interaction with the online pre-learning materials, students' engagement level as measured by their engagement index score (see Chapter 4) and their academic performance.

The design principles of a flipped learning instructional approach encourage students to initially access the online pre-learning materials prior to the in-class sessions (O'Flaherty & Philips, 2015). There is limited research examining students' behavioural patterns with the pre-learning materials which are a contributing factor that influences their level of preparedness prior to the in-class sessions (Dazo et al., 2016; Long et al., 2019). Dooley and Makasis (2020) suggest that variability in students' level of preparedness with the pre-learning materials may hinder their ability to actively engage with the learning activities during the in-class sessions. Research suggests that if students are not accessing the pre-learning material, it may impact their engagement (Dooley & Makasis, 2020) and negatively affect their performance (Long et al., 2019) during the in-class sessions. Although it is widely recognised that students' preparedness can lead to a successful learning experience in a flipped learning environment, limited research has focused on examining the degree to which students interact with the pre-learning material. Studies that have reported on students' interaction with the pre-learning material often rely on student self-reports which may be subjective due to recollection biases (Dazo et al., 2016).

This chapter utilises learning analytics to track student's interaction with the pre-learning material: pre-learning videos and associated pre-learning quizzes. By examining how students use the pre-learning material, a valuable insight can be gained about their online behavioural patterns and the relationship to student engagement and impact on their academic performance.

The following research questions were addressed in this chapter:

1. How do students interact with the pre-learning videos?

a. How does student viewing behaviour correlate with academic performance in the weekly online pre-learning quizzes, overall online pre-learning quiz score and the online in-semester quizzes?

2. How do students interact with the online pre-learning quizzes?
   a. How does student interaction with the pre-learning online quizzes correlated with the online in-semester quizzes?
3. What behavioural patterns can be identified from students' interaction with the online pre-learning material?
   a. How does student behaviour with the pre-learning material change over the course of a semester?
   b. How does student identified learning behaviour related to their academic performance?
   c. How does student identified learning behaviour relate to their behavioural engagement and their academic performance?
4. What are students' perceptions towards the pre-learning material of a partially flipped learning environment?

5.2 Methodology

5.2.1 Participants

The participants consisted of two groups of undergraduate chemistry students enrolled in intermediate chemistry courses in semesters 1 and 2. Group B_1 consisted of students enrolled in 2016 and Group B_2 consisted of students enrolled in 2017. The semester 1 intermediate courses were: Mainstream Molecular Reactivity and Spectroscopy (CHEM2401), Advanced Molecular Reactivity and Spectroscopy (CHEM2911) and Special Studies Program Molecular Reactivity and Spectroscopy (CHEM2915). The semester 2 intermediate courses were: Mainstream Chemical Structure and Stability (CHEM2402), Advanced Chemical Structure and Stability (CHEM2912) and Special Studies Program Chemical Structure and Stability (CHEM2916). See Section 3.9 for a full description for each of the chemistry courses.

5.2.2 Procedures

5.2.2.1 Tracking data

Students' behavioural patterns were based on the aggregated data of students' weekly interactions with the online pre-learning materials across the three intermediate chemistry courses over the course of a semester. For Group B_1, data were collected in 2016 for the intermediate chemistry courses during semester 1 (n = 262) and semester 2 (n = 179). For Group B_2, data were collected in 2017 for the intermediate chemistry courses during semester 1 (n = 247) and semester 2 (n = 175).

Students' behavioural patterns with the weekly online pre-learning materials were captured in a real-time manner in the University's LMS, with LMS click data recoded via a bespoke software (See Section 3.3.2 for more details regarding the use of tracking data). To analyse students' video-viewing behaviours, tracking data captured frequency of views and time of access for each video, which were hosted and delivered through a YouTube channel. However, from the software used it was not possible to determine whether the students watched the videos in part, fully or even repeated certain segments. Excel was used to aggregate the video-viewing data and to analyse weekly trends related to the frequency of access, the distributions of video views as well as total and mean number of video views accessed. An independent two tail t-test with unequal variance was used to measure how variations in students' weekly video-viewing behaviours related to their weekly pre-learning quiz performance. A one-way ANOVA was used to measure the effect of video-viewing behaviours on the students' performance in their overall pre-learning quiz score, their online in-semester quizzes, end of semester examination and overall theory course performance.

To analyse students' behaviours with the online pre-learning quizzes, tracking data captured students' frequency of access, time of access of each attempt, score for each attempt, how many questions were completed for a given attempt, the time spent to select an answer and the time spent reading the provided feedback. Excel was also used to aggregate the data to analyse weekly trends related to the total and mean number of quizzes accessed. A one-way ANOVA was used to measure the effect of pre-learning quiz interactions on the students' performance in their pre-learning quiz score, their online in-semester quizzes, end of semester examination and overall theory course performance.

5.2.2.2 Development of online behavioural pattern

This chapter adapted the approach suggested by Brennan et al. (2019) to explore how students' behavioural pattern and distribution with the online pre-learning materials changes over the course of a semester.

Based on students' interaction with the weekly online pre-learning material, a set of behavioural patterns were identified. The behavioural types are defined according to the relative frequency that students accessed each of the pre-learning materials. For each student, the number of times they accessed the videos and the quizzes was aggregated over the week, and then these two activities were ranked in order of their frequencies. Based on the order of these frequencies, a student interaction was assigned to a specific behavioural type that corresponded to a particular behavioural pattern for each given week (see Table 5.1).

Based on the partially flipped learning model implemented, students can potentially display one of six behavioural patterns on a weekly basis (see Table 5.1). However, it was not possible to capture from the University's LMS one of these behavioural patterns, related to students' only accessing the pre-learning video (V), and as such no further data is reported on this behavioural type, and it was not part of the calculations for behavioural richness or evenness (see Section 5.2.2.2.1).

A one-way ANOVA analyses carried out to investigate differences in the academic performance of varying behavioural patterns derived from students' interactions with the online pre-learning materials.

Table 5.1. Description of the six online behavioural patterns.

Behavioural pattern	Behavioural type	Description
Q	BP_1	Quiz was only accessed
Q>V	BP_2	Quiz was more frequently accessed when compared to the video
Q=V	BP_3	Quiz was equally accessed to the video
V>Q	BP_4	Video was more frequently accessed when compared to the quiz
V	BP_5	Video was only accessed
N/A	BP_6	Neither of the quiz or video were accessed

Note. Q = quiz, V = video.

5.2.2.2.1 Distribution of online behavioural patterns

The range in the distribution of students' online behaviour can be captured by two metrics: richness and evenness (Brennan et al., 2019).

Behavioural richness, R, refers to the number of various behavioural patterns displayed. It provides information on how chemistry students are interacting with the learning resources:

whether all the students are accessing the resources in a similar or different manner in each week. This metric, however, is biased towards rare behaviours as it only considers the presence or absence of behaviours. As such, rare behaviours are classified as 'low richness' and common behaviours are classified as 'high richness'.

Behavioural evenness, E, measures the frequency of each of the six behavioural patterns displayed. It provides insight on whether a particular behaviour pattern is dominant compared to other patterns or whether the different behaviours patterns are evenly distributed across the students. This metric, however, is biased towards common behaviour, as it only considers the frequency of each of the six behaviour types in each week. As such, high evenness refers to behaviours of similar frequencies, and low evenness refers to one or few dominant behaviours. Magurran (1988) defined E as:

$$E = \frac{-\sum_i^n f_i \times \log_2(f_i)}{\log_2(n)} \tag{5.1}$$

Where evenness is bounded between 0 and 1, f_i is the fraction of the cohort that displays behaviour $i,$ and n is the total number of behaviours present in the course in each week.

5.2.2.3 Survey

The survey used in this chapter was internally developed by the research team. It was administered online at the end of the semester to gather information about the students' perception towards their learning experience with the online pre-learning materials. The survey included a combination of closed-ended questions, 5-point Likert-type questions, and open-ended questions (see Appendix E). The closed-ended questions focused on gathering information related to students' access to each of the pre-learning materials and select reason(s) as to why or why not they might have accessed the videos and quizzes. The students were then asked to rate the extent to which they perceived the pre-learning videos to introduce, facilitate, and reinforce their understanding of the weekly concepts covered during the in-class sessions, and the usefulness of pre-learning quizzes using a 5-point Likert Scale (Strongly Disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly Agree = 5).

The students were also asked to rate the link between the weekly videos and associated quizzes and how this aided their learning. Open-ended questions asked students to give their opinion on what aspects they found most helpful in the online pre-learning materials, and their suggestions on how the learning experience with the pre-learning materials may be improved. The codes for the open-ended responses were analysed by thematic analysis. A combination of deductive and inductive codes was used to review students' responses to the open-ended questions. The use of deductive codes was derived from the existing literature on students' perception towards the pre-learning material (See section 2.5.12) whereas inductive codes were derived from the collected data (Saldaña, 2012). For example, the *'flexible access'* the pre-learning material offers was considered as a deductive code as the students' responses obtained in this study aligned with those identified in similar research on students' perception towards the pre-learning material in a flipped learning environment (Christiansen, 2014; Mooring et al., 2016; Roach, 2014; Shattuck, 2016). The inductive codes were explicitly related to the design of the pre-learning materials implemented in the chemistry courses. Students' individual responses were compared, using thematic analysis common themes were identified and similar responses were aggregated under one code, for instance *'auto-generated quiz feedback'* was perceived to be a valuable feature embedded in the pre-learning quizzes.

5.3 Results

5.3.1 Participation rates for each intermediate chemistry course

The overall participation rate and that of each of the three intermediate chemistry courses for Group B_1 and Group B_2 across both semesters are shown in Table 5.2 and Table 5.3 respectively.

For Group B_1, a total of 145 (49%) students completed both semester 1 and semester 2 intermediate chemistry courses. For Group B_2, a total of 124 (37%) students completed both semester 1 and semester 2 intermediate chemistry courses.

Table 5.2. Participation rate by intermediate chemistry course in Group B_1 across both semesters.

	Semester 1			Semester 2	
	Participants	Participation rate		Participants	Participation rate
	n	%		*n*	%
CHEM2401	172	97	CHEM2402	97	80
CHEM2911	81	100	CHEM2912	76	97
CHEM2915	9	38	CHEM2916	6	46
Total	262	93	Total	179	84

Table 5.3. Participation rate by intermediate chemistry course in Group B_2 across both semesters.

	Semester 1			Semester 2	
	Participants	Participation rate		Participants	Participation rate
	n	%		*n*	%
CHEM2401	155	87	CHEM2402	120	93
CHEM2911	60	97	CHEM2912	43	100
CHEM2915	20	91	CHEM2916	11	58
Total	235	90	Total	174	90

5.3.2 Comparison of student groups

To compare the performance of Group B_1 with Group B_2 in each semester it is necessary to determine that there is a homogeneity of variances, indicating that the variance of Group B_1 with Group B_2 is the same for each semester. The Weighted Average Mean (WAM) score was used to draw comparisons between the various groups (see Section 4.4.2 for further details regarding WAM scores). The analysis was carried out only for students who had a WAM score (see Table 5.4).

Table 5.4. Cohort response rate for students with WAM score across all three intermediate chemistry courses in Groups B_1 and B_2.

	Semester 1		Semester 2	
	Respondents with WAM	Response rate	Respondents with WAM	Response rate
	n	%	*n*	%
Group B_1	219	84	158	88
Group B_2	200	85	134	77

The results for semester 1 indicate that there was no significant difference in the WAM score between students in Group B_1 and Group B_2 ($t_{417} = 1.74, p = 0.083$). The WAM score for Group B_1 (M = 68.93, SD =10.60) was not significantly different from that of Group B_2 (M = 70.82, SD = 11.69). These results suggest that comparison between groups during semester 1 can be carried out as the variance was similar and no statistically significant difference was observed in the WAM scores.

The results for semester 2 indicate that there was no significant difference in the WAM score between students in Group B_1 and Group B_2 ($t_{290} = 0.8$, $p = 0.936$). The WAM score for Group B_1 (M = 70.18, SD = 9.29) was not significantly different from that of Group B_2 (M = 70.27, SD =11.60). These results suggest that comparison between groups during semester 2 can be carried out as the variance was similar and no statistically significant difference was observed in the WAM scores (see Table 5.5).

Table 5.5. Mean WAM scores to determine sample representation of the Groups B_1 and B_2.

	Semester 1			Semester 2		
	n	M	SD	*n*	M	SD
Group B_1	219	68.93	10.60	158	70.18	9.29
Group B_2	200	70.82	11.69	134	70.27	11.60

Note. M = mean, SD = standard deviation.

5.3.3 Interaction with pre-learning videos in a partially flipped learning environment

5.3.3.1 Percentage of student accessing pre-learning videos

The percentage of students accessing the 10 weekly videos over the course of each semester are presented in Figure 5.1. As previously noted in Section 3.12, no weekly pre-learning materials are presented during the weeks in the semester in which the online in-semester tutorial quizzes take place (week 5 and week 10). The weeks corresponding to the pre-learning videos for the first semester and second semester are listed in Table 3.7. For Group B_1 the viewing access for students during the first semester was lower than that of the second semester. The range of viewing access in semester 1 was from 67% to 83% whereas for semester 2, the range was from 89% to 96% (see Figure 5.1).

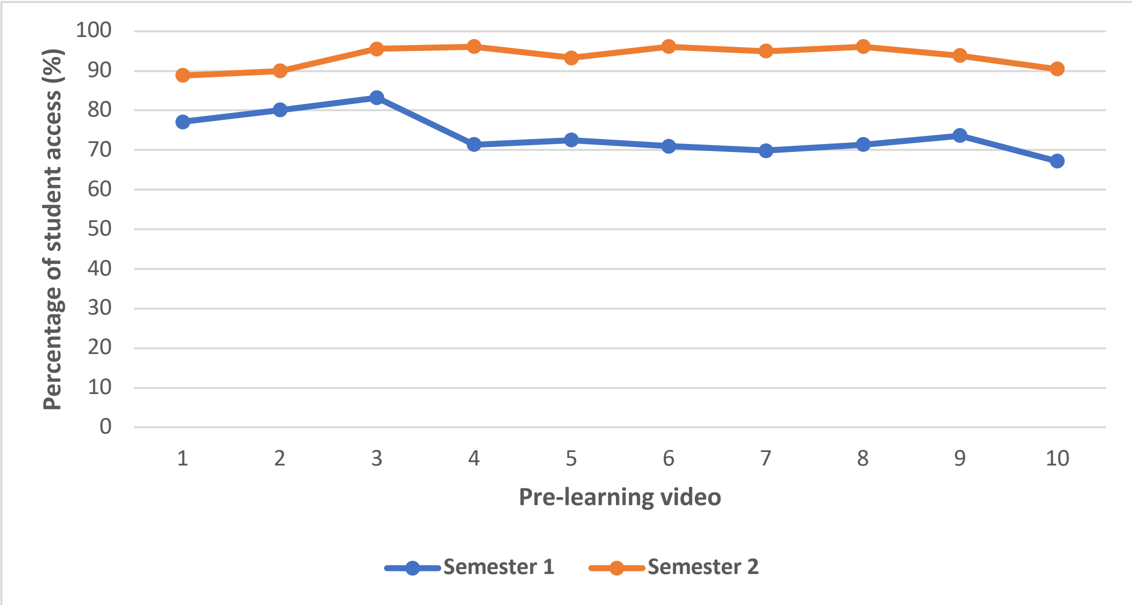

Figure 5.1. Percentage of students accessing weekly pre-learning videos for Group B_1 across semester 1 (n = 262) and semester 2 (n = 179).

Similar trends can be observed for Group B_2, whereby viewing access for students during the first semester was relatively lower than that of the second semester. The range of viewing access in semester 1 was from 69% to 87% whereas in semester 2, the range was from 72% to 94% (see Figure 5.2).

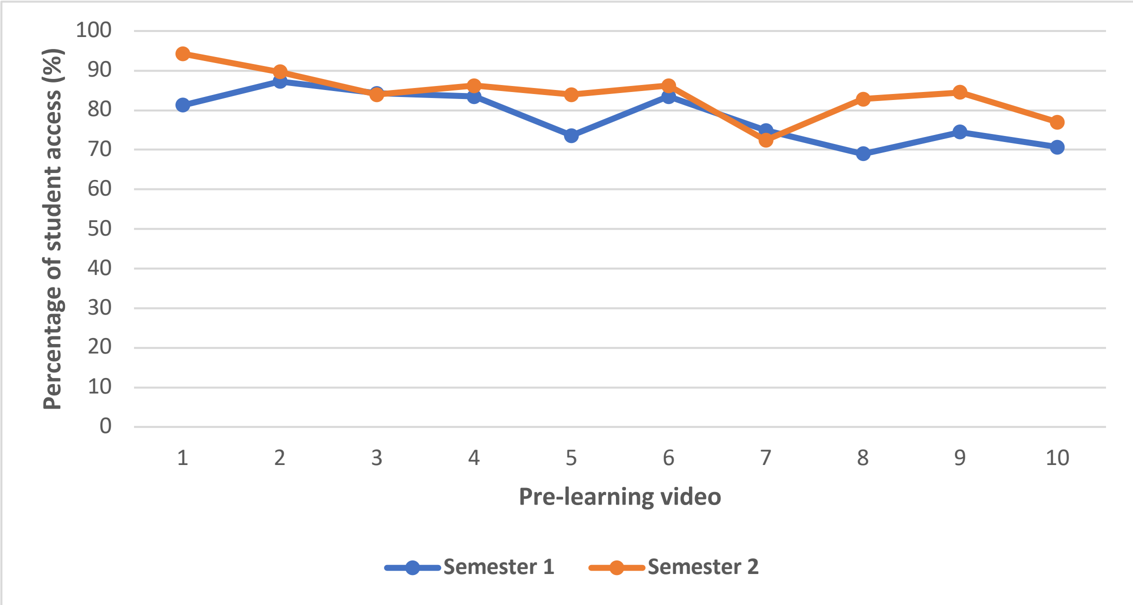

Figure 5.2. Percentage of students accessing weekly pre-learning videos for Group B_2 across semester 1 (n = 235) and semester 2 (n = 174).

5.3.3.2 Distribution of pre-learning video views

As previously noted in Section 3.12, the same online pre-learning materials were used across all three levels of the intermediate chemistry courses. Initial analysis revealed similar weekly patterns in the distribution of video views across all three courses for Groups B_1 and B_2. The subsequent analyses related to the distribution of video views were carried out at a cohort level by combining the students from all three intermediate chemistry courses for each semester rather than separating them by courses (see Figures 5.3 and Figure 5.6). The distribution of videos viewed by the students ranged from 0 to 4 (or more) throughout each semester.

For Group B_1, students' viewing behaviour of the weekly videos varied across both semesters. Over the course of semester 1, an average of 26% of students did not view the videos, 37% viewed the videos once, and 37% viewed the videos more than once (see Figure 5.3). For semester 2, an average of 6% of students did not view the videos, 24% viewed the videos once, and 70% viewed the video more than once (see Figure 5.4).

Similar trends were observed in Group B_2, with viewing behaviour of the weekly videos varying across both semesters. Over the course of semester 1, an average of 22% of students did not view the videos, 40% viewed the videos once, and 38% viewed the videos more than once (See Figure 5.5). For semester 2, an average of 16% of students did not view the videos, 21% viewed the videos once, and 63% viewed the video more than once (see Figure 5.6).

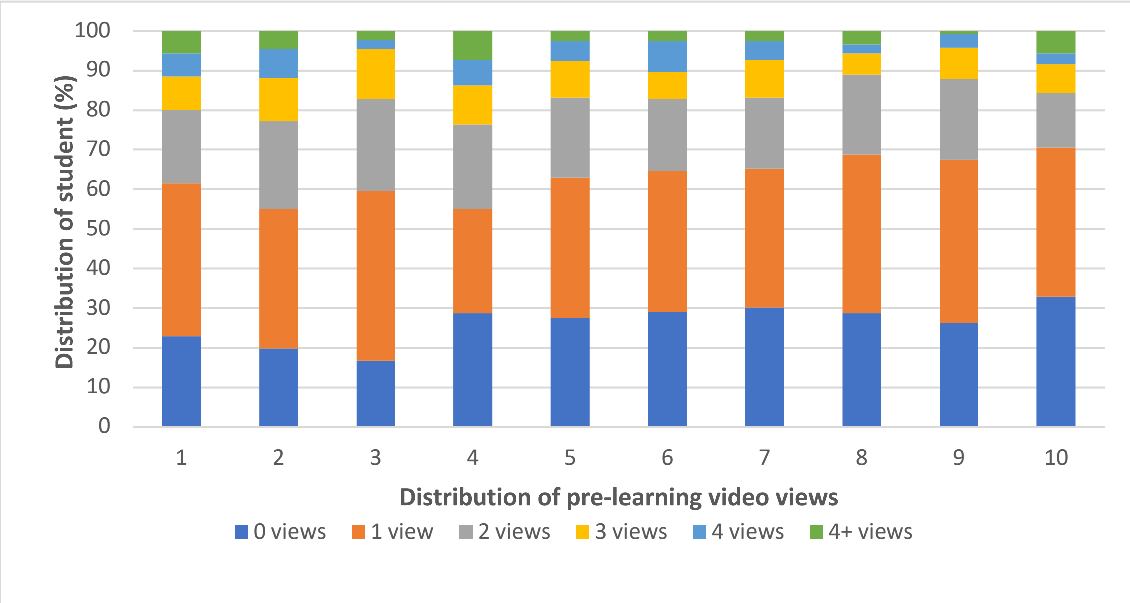

Figure 5.3. Distribution of students for the weekly pre-learning video views for Group B_1 semester 1 (n = 262).

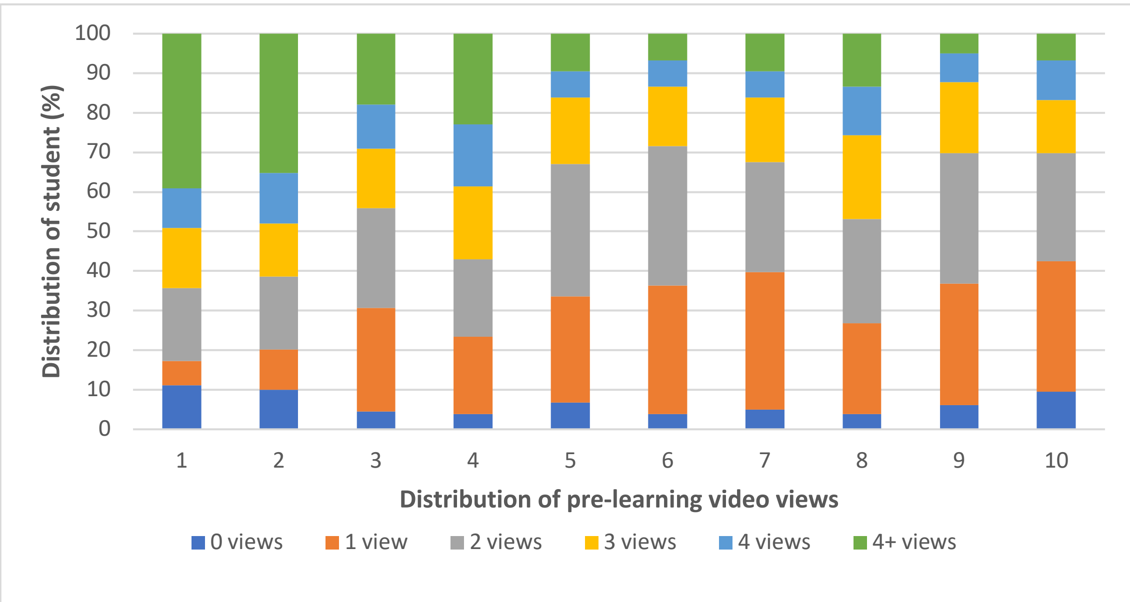

Figure 5.4. Distribution of students for the weekly pre-learning video views for Group B_1 semester 2 (n = 179).

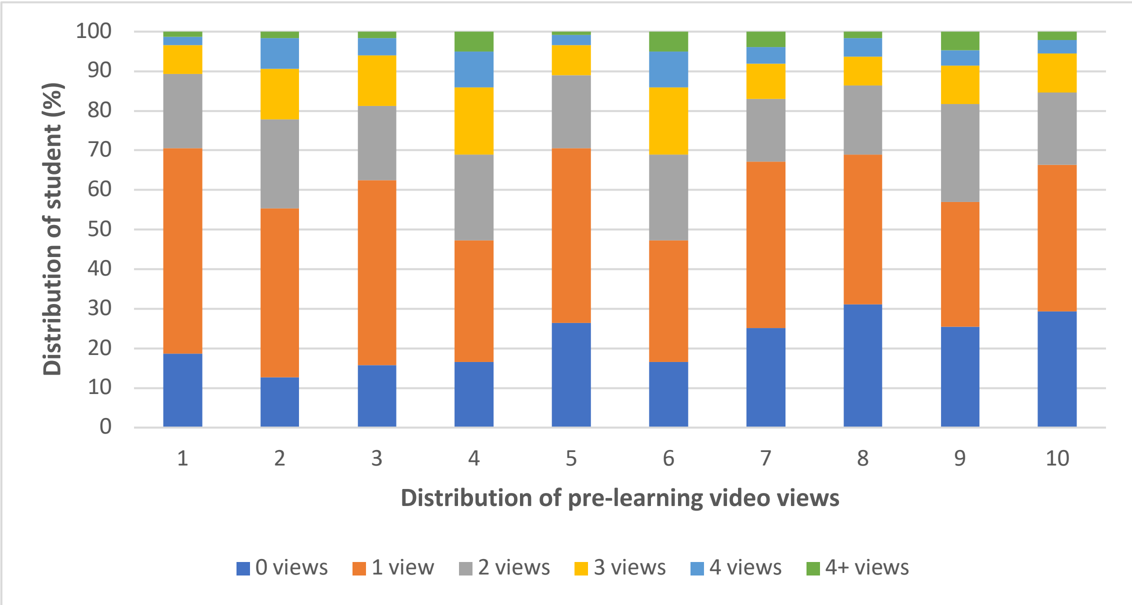

Figure 5.5 Distribution of students for the weekly pre-learning video views for Group B_2 semester 1 (n = 235).

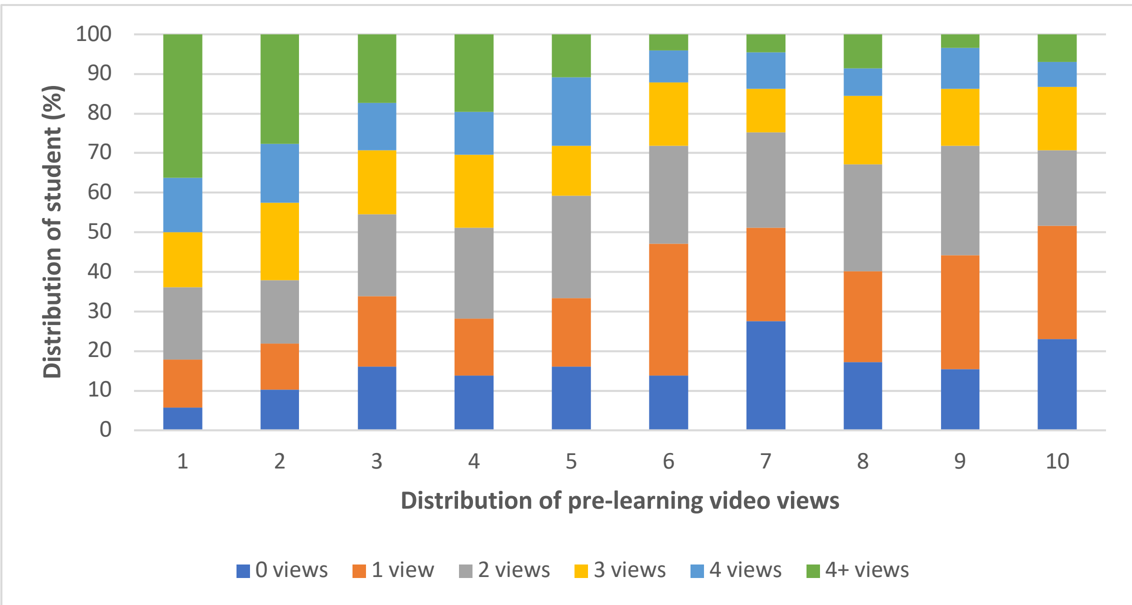

Figure 5.6. Distribution of students for the weekly pre-learning video views for Group B_2 semester 2 (n = 174)**.**

5.3.3.3 Video view access

The total number of video views was analysed for Group B_1 and Group B_2 at a cohort level for each semester by combining the students from all three intermediate chemistry courses rather than separating them by courses (see Figures 5.7 to Figure 5.10). The mean number of video views over the course of the semester was then analysed for each of the three courses in Group B_1 and Group B_2 (see Table 5.6).

The total number of video views per week for Group B_1 varied across both semesters. As semester 1 progressed, no clear pattern was observed with video views varying from week to week with the fourth video reaching the most views (444) and the remaining videos between 320-440 views (see Figure 5.7). The average video views at a cohort level were relatively similar with most videos watched once or twice (see Table 5.6). At a course level, the fourth video appeared to be the most frequently watched for CHEM2401 and CHEM2911. For CHEM2915, the second, third and tenth videos were the most frequently watched.

As semester 2 progressed, the number of videos viewed dropped, with the first video reaching 749 views and the remaining videos between 350 to 660 views (see Figure 5.8). The average video views at a cohort level varied from week to week, with most videos watched on average two or three times (see Table 5.6). At a course level, the first video appeared to be the most frequently watched across all three chemistry courses.

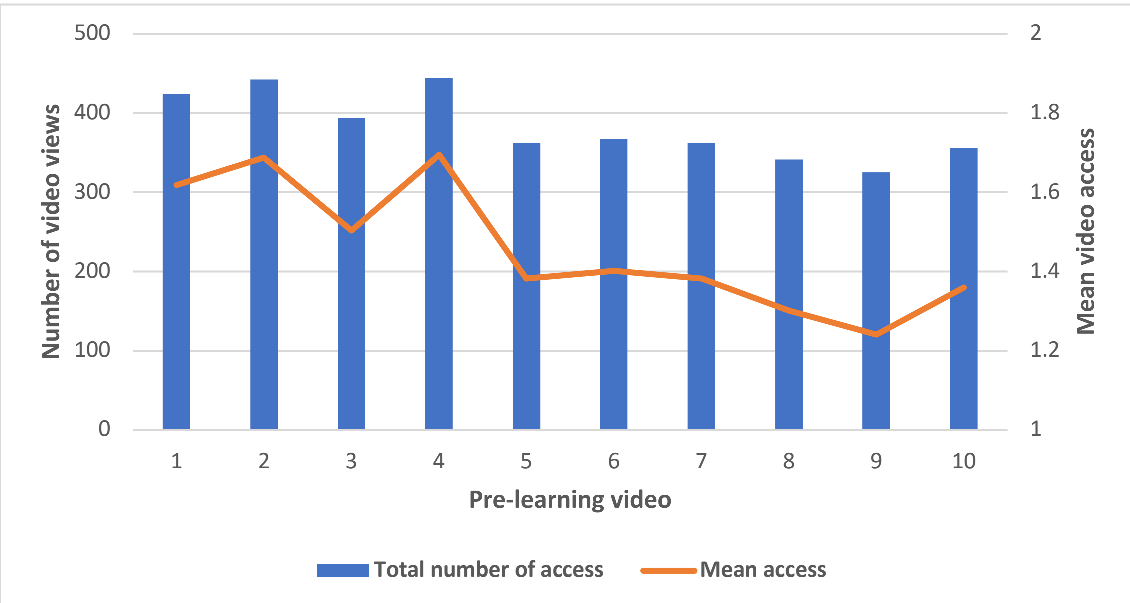

Figure 5.7. Total pre-learning video views and mean pre-learning video views for Group B_1 semester 1 ($n = 262$).

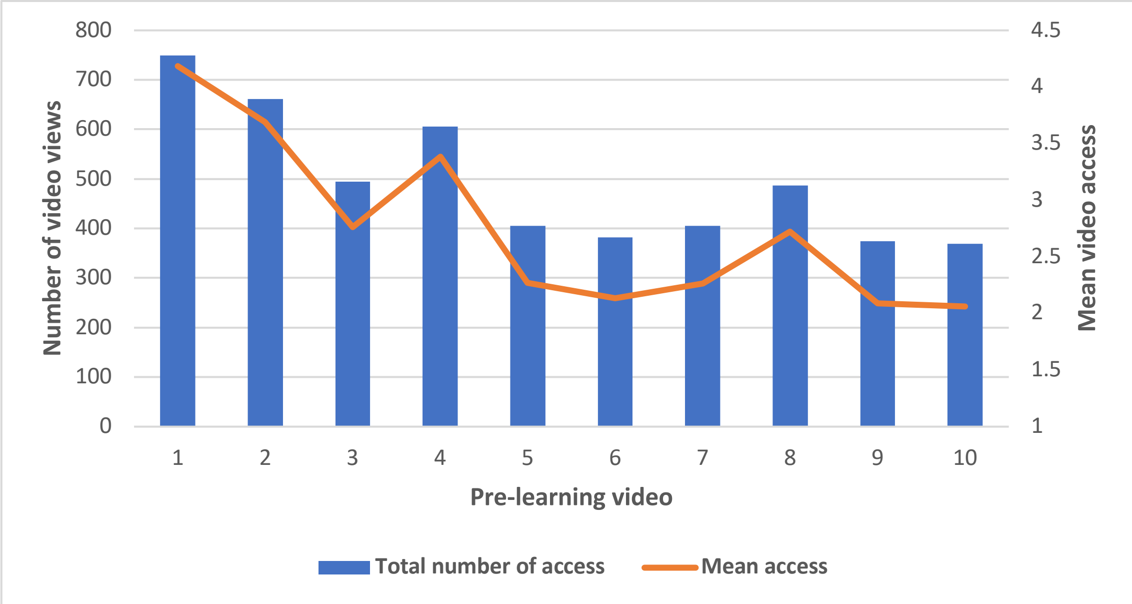

Figure 5.8. Total pre-learning video views and mean pre-learning video views for Group B_1 semester 2 (n = 179).

The total number of video views per week for Group B_2 varied across both semesters. As the semester 1 progressed, no clear pattern was observed with video views varying from week to week with the fourth and sixth videos reaching the most views (444) and the remaining videos between 270-440 views (see Figure 5.9). The average video views at a cohort level were relatively similar with most videos watched on average once or twice (see Table 5.6). At a course level, the fourth and sixth videos appeared to be the most frequently watched for CHEM2401 and CHEM2911. For CHEM2915, the second and third videos was the most frequently watched.

As semester 2 progressed, the number of videos viewed dropped with the first video reaching 664 views and the remaining videos between 310 to 610 views (see Figure 5.10). The average video views at a cohort level varied from week to week, with most videos watched on average two or three times (see Table 5.6). At a course level, the first video appeared to be the most frequently watched across all three chemistry courses.

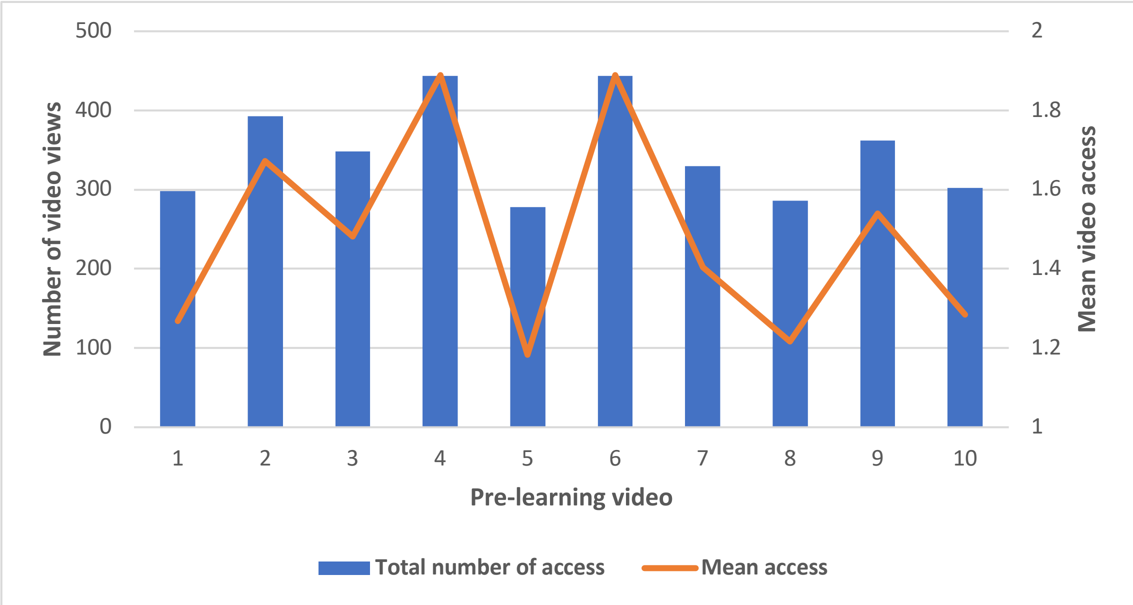

Figure 5.9. Total pre-learning video views and mean pre-learning video views for Group B_2 semester 1 (n = 235).

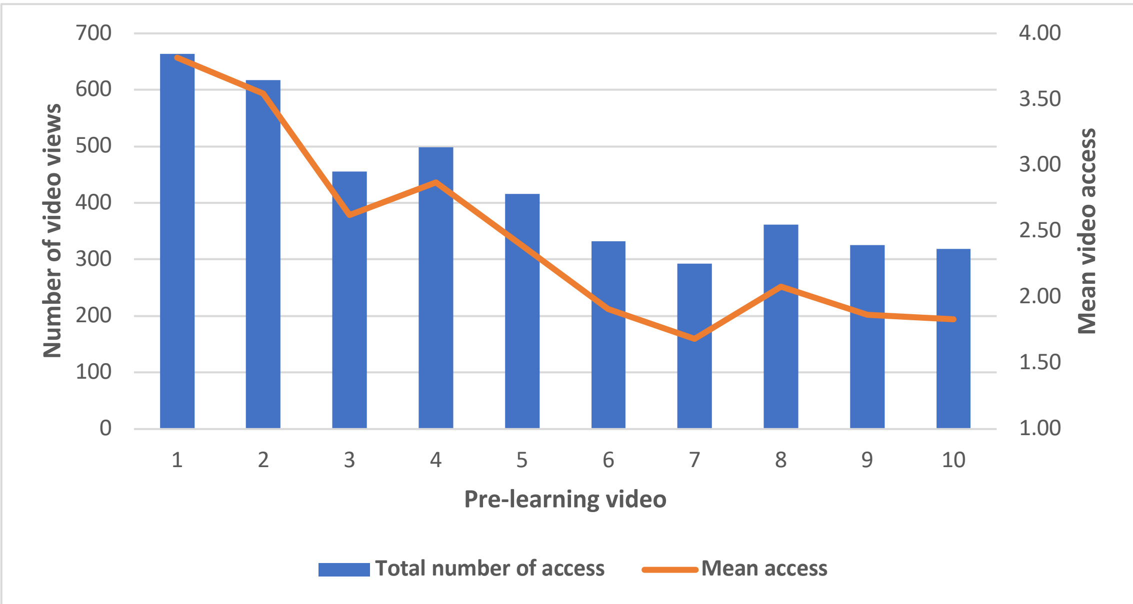

Figure 5.10. Total pre-learning video views and mean pre-learning video views for Group B_2 semester 2 (n = 174)**.**

Table 5.6. Mean number of video views for Group B_1 and Group B_2 across both semesters.

	Cohort ^{s1}		CHEM2401^{s1}		CHEM2911^{s1}		CHEM2915^{s1}		Cohort ^{s2}		CHEM2402^{s2}		CHEM2912^{s2}		CHEM2916^{s2}	
Group B_1	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
1	1.62	1.74	1.84	1.93	1.19	1.17	1.33	1.66	4.18	3.16	4.24	3.32	4.16	3.00	3.67	3.74
2	1.69	1.49	1.84	1.59	1.38	1.19	1.44	1.42	3.69	2.62	3.38	2.53	4.13	2.73	3.17	2.14
3	1.50	1.23	1.62	1.34	1.27	0.91	1.44	1.33	2.76	1.98	2.43	1.78	3.26	2.14	1.67	1.86
4	1.69	1.74	1.85	1.67	1.52	1.97	0.22	0.44	3.39	2.47	3.18	2.30	3.76	2.67	2.00	2.00
5	1.38	1.31	1.42	1.40	1.43	1.12	0.22	0.67	2.27	1.57	2.34	1.66	2.25	1.45	1.33	1.21
6	1.40	1.45	1.45	1.50	1.42	1.38	0.22	0.44	2.13	1.39	2.07	1.43	2.20	1.29	2.33	2.07
7	1.38	1.59	1.45	1.75	1.33	1.23	0.44	0.73	2.26	1.74	2.32	1.84	2.30	1.60	0.83	1.17
8	1.30	1.50	1.34	1.45	1.23	1.67	1.11	0.78	2.72	1.90	2.72	1.72	2.78	2.13	2.00	1.79
9	1.24	1.11	1.27	1.19	1.21	0.93	0.89	1.27	2.09	1.35	2.13	1.32	2.12	1.39	1.00	0.89
10	1.36	1.70	1.39	1.79	1.28	1.30	1.44	2.96	2.06	1.48	1.99	1.52	2.17	1.44	1.83	1.47
Group B_2	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
1	1.27	1.03	1.44	1.11	0.95	0.83	0.90	0.64	3.82	2.52	3.93	2.59	3.51	2.40	3.82	2.32
2	1.67	1.27	1.74	1.28	1.75	1.26	0.95	1.05	3.55	2.59	3.70	2.56	3.26	2.66	3.00	2.76
3	1.48	1.13	1.57	1.11	1.42	1.08	0.95	1.32	2.62	2.16	2.73	2.09	2.72	2.35	1.00	1.55
4	1.89	1.47	1.92	1.43	2.15	1.51	0.85	1.23	2.87	2.28	2.78	1.94	3.56	2.98	1.09	1.38
5	1.18	1.04	1.26	1.04	1.12	1.09	0.75	0.85	2.39	1.79	2.48	1.68	2.63	1.99	0.45	0.82
6	1.89	1.47	1.92	1.43	2.15	1.51	0.85	1.23	1.91	1.54	1.93	1.39	2.07	1.92	1.00	1.26
7	1.40	1.41	1.44	1.46	1.57	1.35	0.65	0.99	1.68	1.58	1.83	1.62	1.53	1.52	0.64	0.92
8	1.22	1.19	1.31	1.17	1.22	1.19	0.55	1.19	2.08	1.68	2.23	1.67	1.88	1.72	1.27	1.49
9	1.54	1.29	1.50	1.34	1.90	1.66	0.80	1.82	1.87	1.36	1.88	1.36	2.09	1.34	0.82	0.98
10	1.29	1.25	1.20	1.06	1.68	1.49	0.75	1.55	1.83	1.75	1.93	1.80	1.84	1.57	0.82	1.66

Note. M = mean, SD = standard deviation, S1 = semester 1 course, S2 = semester 2 course, Group B_1: cohort^{s1}= semester 1 cohort (n = 262), CHEM2401(n = 172), CHEM2911 (n = 81), CHEM2915 (n = 9), cohort^{s2} = semester 2 cohort (n = 179), CHEM2402 (n = 97), CHEM2912 (n = 76) and CHEM2915 (n = 6), Group $B_{2:}$ cohort$_1$= semester 1 cohort (n = 235), CHEM2401 (n = 155), CHEM2911 (n = 60), CHEM2915 (n = 20), cohort$_2$ = semester 2 cohort (n = 174) CHEM2402 (n =120) CHEM2912 (n = 43) and CHEM2915 (n =11).

5.3.4 Video interaction and impact on academic performance

5.3.4.1 Differences in video interaction between no video views and video views

An independent two tail *t*-test with unequal variance was conducted to determine whether there was any difference in the weekly quiz performance between the group of students who did not view the video and those that did. To compare students' weekly video interactions effect on the associated quizzes, the mean quiz score over the total number of quiz attempts was used rather than the students final quiz score. Using the mean quiz score instead of their final quiz score provides a more accurate measure for this analysis of their weekly quiz behaviour as often the final quiz score would have been either a nine or a ten. The differences in weekly quiz performance between the group of students who did not view the video and those that viewed it was analysed for Group B_1 and Group B_2 at a cohort level for each of the semesters. Moreover, differences in weekly quiz performance were compared between those students that viewed the video once to those that viewed it multiple times.

Student interaction with the weekly videos and its effect on the associated quizzes for Group B_1 varied across both semesters. For semester 1, there were significant differences in mean weekly quiz performance between the group of students who did not view the video to those that viewed it (once or multiple times) (see Table 5.7). The students who viewed the videos once or multiple times performed significantly better in the associated quizzes across the whole semester than those who did not view it. There were inconsistent results when comparing the weekly quiz performance of students who viewed the video once to those that viewed it multiple times. There were significant differences in only three of the ten weeks; video 2, video 7 and video 10. The students who viewed the video once performed significantly better in the associated quizzes than those who viewed it multiple times.

For semester 2, there were significant differences in mean weekly quiz performance between the group of students who did not view the video to those that viewed it (once or multiple times) (see Table 5.7). The students who viewed the videos once or multiple times performed significantly better in the associated quizzes across the whole semester than those who did not view it. There were inconsistent results when comparing the weekly quiz performance of students who viewed the video once to those that viewed it multiple times. There was a significant difference in one week; video 9. The students who viewed the video once performed significantly better in the associated quizzes than those who viewed it multiple times.

Table 5.7. Video interaction and impact on academic performance for Group B_1 for semester 1 (n = 262) and semester 2 (n = 179).

	Not viewed		Viewed once		Viewed multiple times		Viewed (once or multiple times)		Significance between not viewed and viewed	Significance between viewed once and viewed multiple times
Semester 1	M	SD	M	SD	M	SD	M	SD	p value	p value
1	3.61	4.17	8.20	4.17	7.70	1.90	5.04	3.47	p < 0.001***	p = 0.100
2	3.14	3.22	5.80	3.22	4.60	2.67	5.12	2.81	p < 0.001***	p = 0.002***
3	4.67	3.96	6.76	3.96	6.35	2.20	6.65	2.24	p = 0.003	p = 0.175
4	2.63	3.55	5.33	3.55	4.96	2.49	5.12	2.52	p < 0.001***	p = 0.390
5	3.46	3.94	6.41	3.94	5.56	2.30	5.98	2.53	p < 0.001***	p = 0.190
6	3.29	3.93	5.98	3.93	6.21	2.40	6.09	2.33	p < 0.001***	p = 0.506
7	3.38	4.02	5.99	4.02	5.17	2.11	5.59	2.43	p < 0.001***	p = 0.022*
8	5.74	4.08	7.38	4.08	6.72	2.52	7.09	2.65	p = 0.009	p = 0.087
9	3.86	4.25	5.89	4.25	5.49	2.39	5.71	2.44	p = 0.001**	p = 0.247
10	2.94	4.02	6.47	4.02	5.12	2.44	5.88	2.66	p < 0.001***	p < 0.001***
Semester 2	M	SD	M	SD	M	SD	M	SD	p value	p value
1	2.98	1.37	3.70	2.33	3.47	1.81	3.49	1.84	p = 0.147	p = 0.774
2	0	0	4.07	2.03	3.52	1.53	3.58	1.59	p < 0.001***	p = 0.283
3	0.71	1.48	4.98	1.96	4.58	1.94	4.69	1.95	p < 0.001***	p = 0.236
4	0.75	1.98	4.53	2.20	4.61	1.66	4.59	1.78	p = 0.002**	p = 0.844
5	0.63	1.82	5.40	1.84	5.76	3.88	5.56	2.40	p < 0.001***	p = 0.430
6	1.90	3.78	5.90	2.43	5.64	2.12	5.73	2.22	p = 0.037	p = 0.483
7	1.05	2.08	4.47	2.42	5.02	1.96	4.82	2.15	p < 0.001***	p = 0.127
8	1.25	2.51	4.30	2.57	4.55	1.65	4.49	11.90	p = 0.014	p = 0.571
9	0.36	1.21	6.13	2.80	5.12	2.44	5.45	2.60	p < 0.001***	p = 0.024*
10	1.42	2.11	5.18	1.62	5.08	1.34	5.12	1.45	p < 0.001***	p = 0.688

Note. M = mean, SD = standard deviation, *p < 0.05 ** p < 0.01 ***p < 0.001.

Student interaction with the weekly videos and its effect on the associated quizzes for Group B_2 varied across both semesters. There were significant differences in the mean weekly quiz performance in semester 1 between the group of students who did not view the video to those that viewed the video once or multiple times (see Table 5.8). The students who viewed videos once or multiple times performed significantly better in the associated quizzes across the whole semester than those who did not view the videos. There were inconsistent results, however, when comparing the weekly quiz performance of students who viewed the video once to those that viewed it multiple times. There were significant differences in only four of the ten weeks; video 2, video 6, video 7 and video 8. The students who viewed the video once performed significantly better in the associated quizzes than those who viewed the video multiple times.

For semester 2, there were significant differences in the mean weekly quiz performance between the group of students who did not view the video to those that viewed the video once or multiple times (see Table 5.8). The students who watched the videos once or multiple times performed significantly better in the associated quizzes than those who did not view the videos. The students who viewed the videos once or multiple times performed significantly better in the associated quizzes across the whole semester than those who did not view the videos. There were inconsistent results when comparing the weekly quiz performance of students who viewed the video once to those that viewed it multiple times. There were significant differences in only three of the ten weeks; video 1, video 2, and video 10. The students who viewed the video once performed significantly better in the associated quizzes than those who viewed the video multiple times.

Table 5.8. Video interaction and impact on academic performance for Group B_2 for semester 1 (n = 235) and semester 2 (n = 174).

	Not viewed		Viewed once		Viewed multiple times		Viewed (once or multiple times)		Significance between not viewed and viewed	Significance between viewed once and viewed multiple times
Semester 1	M	SD	M	SD	M	SD	M	SD	p value	p value
1	7.13	4.10	9.63	1.14	9.43	1.8	9.56	1.41	$p < 0.001$***	$p = 0.410$
2	2.35	3.37	4.65	2.72	3.82	2.22	4.23	2.50	$p = 0.006$**	$p = 0.019$*
3	2.61	3.15	6.19	2.14	5.80	1.97	6.01	2.07	$p < 0.001$***	$p = 0.182$
4	1.22	2.13	5.17	2.29	4.56	2.16	4.78	2.22	$p < 0.001$***	$p = 0.071$
5	5.48	3.81	7.23	3.33	6.74	3.83	7.03	3.53	$p = 0.006$**	$p = 0.395$
6	2.96	2.61	5.1	2.23	4.42	2.41	4.67	2.36	$p < 0.001$***	$p = 0.048$*
7	1.34	2.45	5.27	2.18	4.46	1.88	4.91	2.08	$p < 0.001$***	$p = 0.009$**
8	2.08	2.77	6.61	3.14	5.63	2.77	6.17	3.01	$p < 0.001$***	$p = 0.037$*
9	0.77	1.79	4.54	2.15	4.35	1.72	4.43	1.91	$p < 0.001$***	$p = 0.535$
10	1.11	1.98	5.02	2.18	4.82	2.27	4.93	2.22	$p < 0.001$***	$p = 0.568$
Semester 2	M	SD	M	SD	M	SD	M	SD	p value	p value
1	0.59	1.95	5.25	2.27	3.92	1.92	4.09	2.01	$p < 0.001$***	$p = 0.017$**
2	0	0	4.25	1.49	3.16	1.39	3.30	1.45	$p < 0.001$***	$p = 0.005$**
3	0.60	1.75	4.54	1.49	4.54	1.57	4.54	1.55	$p < 0.001$***	$p = 0.958$
4	1.28	2.18	4.27	1.17	4.70	1.76	4.63	1.68	$p < 0.001$***	$p = 0.139$
5	0.99	2.57	5.23	1.59	5.17	1.64	5.18	1.63	$p < 0.001$***	$p = 0.861$
6	1.26	2.57	6.32	2.27	6.06	2.12	6.16	2.17	$p < 0.001$***	$p = 0.483$
7	0.96	2.22	5.30	2.13	4.61	1.85	4.84	1.96	$p < 0.001$***	$p = 0.081$
8	1.62	2.78	5.29	2.30	4.92	1.83	5.02	1.97	$p < 0.001$***	$p = 0.374$
9	1.45	2.63	5.73	2.66	5.21	2.33	5.39	2.45	$p < 0.001$***	$p = 0.244$
10	1.47	2.56	5.44	1.26	4.91	1.01	5.11	1.13	$p < 0.001$***	$p = 0.014$*

Note. M = mean, SD = standard deviation, *$p < 0.05$ ** $p < 0.01$ ***$p < 0.001$.

5.3.5 Interaction with online pre-learning quizzes in a partially flipped learning model

The total number of quizzes accessed was analysed for Group B_1 and Group B_2 at a cohort level for each semester by combining the students from all three intermediate chemistry courses rather than separating them by courses (see Figures 5.11 to Figure 5.14). As previously noted in Section 3.12, no weekly pre-learning materials are presented during the weeks in the semester in which the online in-semester tutorial quizzes take place (week 5 and week 10). The mean number of quizzes accessed over the course of the semester was then analysed for each of the three courses in Group B_1 and Group B_2 (see Table 5.9).

The total number of quizzes accessed per week for Group B_1 varied across both semesters. As semester 1 progressed, no clear pattern was observed with quiz access varying from week to week with the fourth quiz reaching the most access (2408) and the remaining quizzes between 700-1800 access (see Figure 5.11). The average number of quizzes accessed at a cohort level varied across the weeks (see Table 5.9). At a course level, the fourth quiz appeared to be the most frequently accessed for CHEM2401 and CHEM2911. For CHEM2915, the ninth quiz was the most frequently accessed.

As semester 2 progressed, the number of quizzes accessed increased with the first and second quiz accessed 2780 and 2992 times respectively and the remaining quizzes accessed between 970 to 2500 times (see Figure 5.12). The average number of quizzes accessed at a cohort level varied from week to week (see Table 5.9). At a course level, the first quiz appeared to be the most frequently accessed across all three chemistry courses.

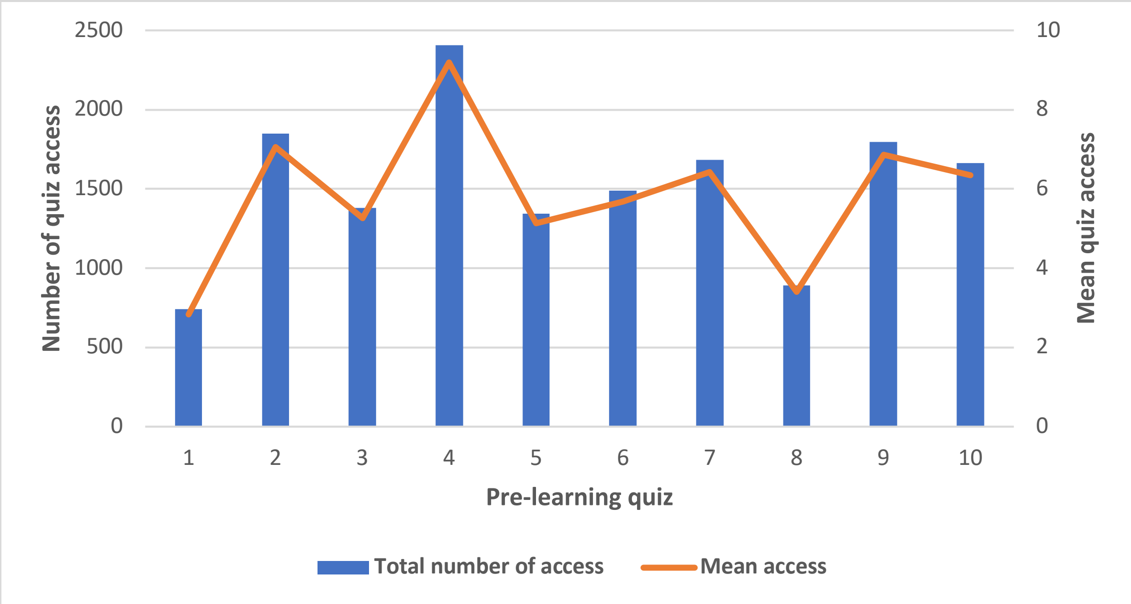

Figure 5.11. Total pre-learning quiz access and mean pre-learning quiz access for Group B_1 semester 1 (n = 262).

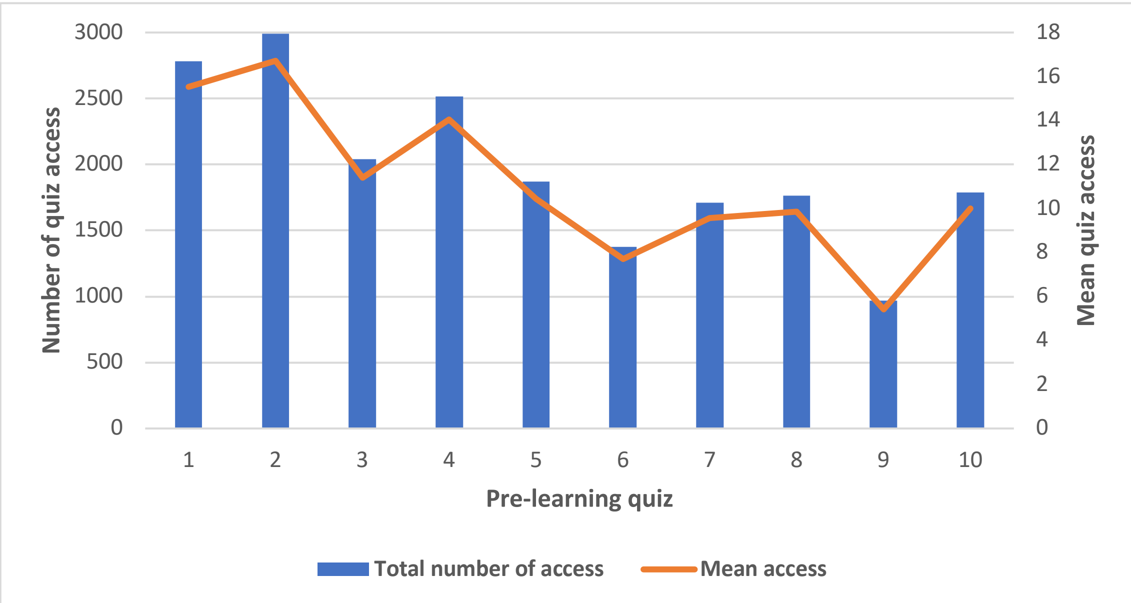

Figure 5.12. Total pre-learning quiz access and mean pre-learning quiz access for Group B_1 semester 2 (n =179).

The total number of quizzes accessed per week for Group B_2 varied across both semesters. As semester 1 progressed, no clear pattern was observed with quiz access varying from week to week with the fourth quiz reaching the most access (2541) and the remaining quizzes between 330-2130 access (see Figure 5.13). The average number of quizzes accessed at a cohort level varied across the weeks (see Table 5.9). At a course level, the fourth quiz appeared to be the most frequently accessed for CHEM2401 and CHEM2911. For CHEM2915, the second quiz was the most frequently accessed.

As semester 2 progressed, the number of quizzes accessed increased with the second quiz being accessed 2582 times and the remaining quizzes between 970 to 2500 access (see Figure 5.14). The average number of quizzes accessed at a cohort level varied from week to week (see Table 5.9). At a course level, the second quiz appeared to be the most frequently accessed across all three chemistry courses.

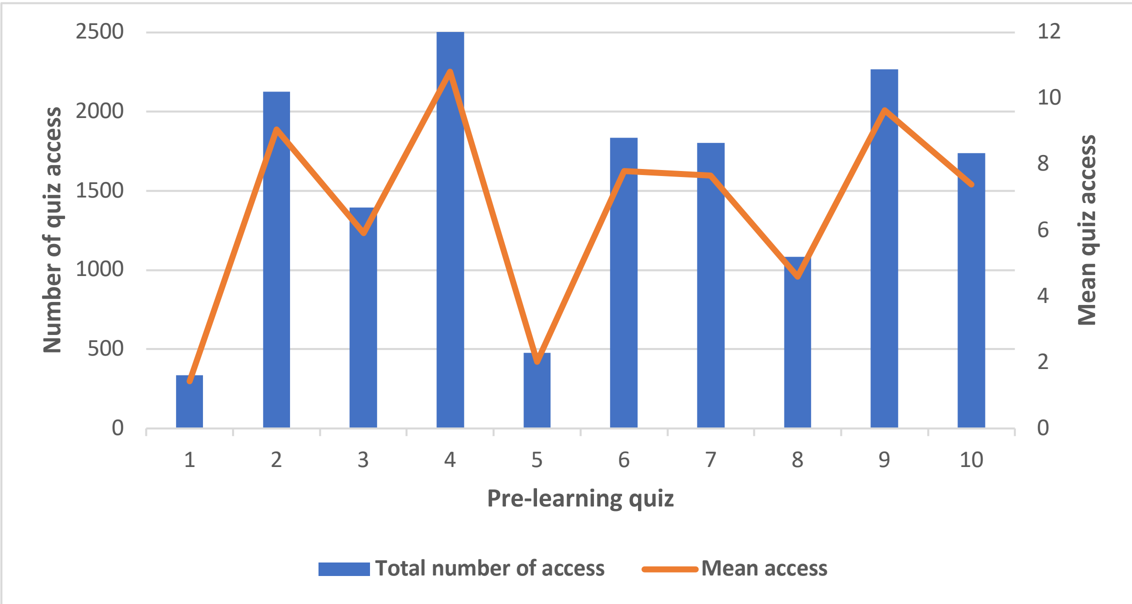

Figure 5.13. Total pre-learning quiz access and mean pre-learning quiz access for Group B_2 semester 1 (n = 235).

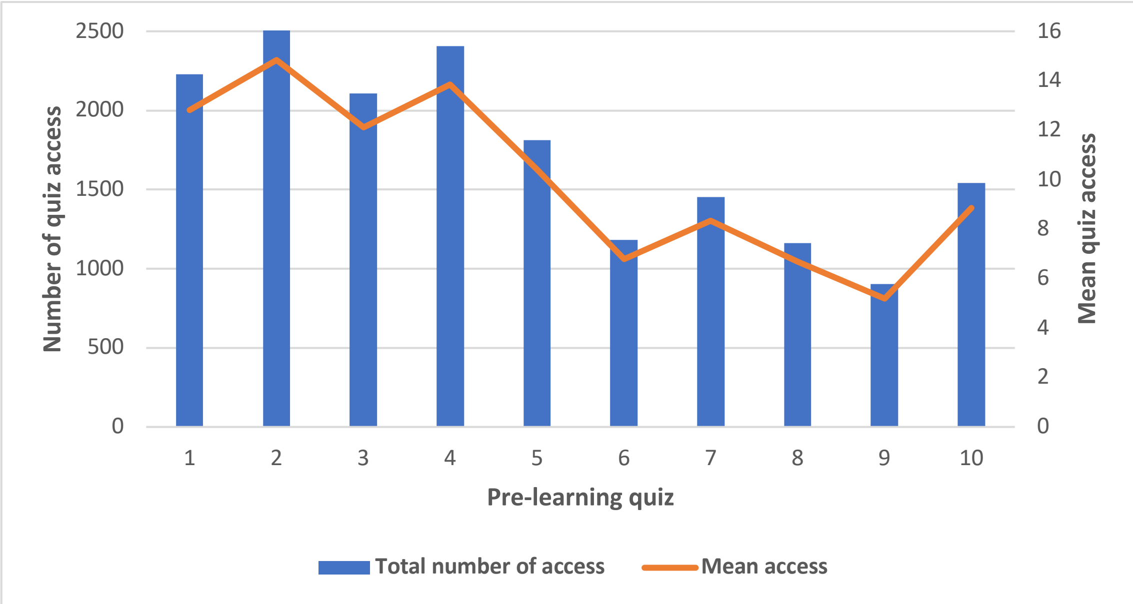

Figure 5.14. Total pre-learning quiz access and mean pre-learning quiz access for Group B_2 semester 2 (n = 174).

Table 5.9. Mean number of quiz attempts for Group B_1 and Group B_2 across both semesters.

	Cohort ^{s1}		CHEM2401^{s1}		CHEM2911^{s1}		CHEM2915^{s1}		Cohort ^{s2}		CHEM2402^{s2}		CHEM2912^{s2}		CHEM2916^{s2}	
Group B_1	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
1	2.83	3	3.10	3.34	2.32	2.10	2.33	2.45	15.53	15.88	18.43	19.17	12.49	10.07	7.17	3.82
2	7.06	7.23	8.23	8.04	5.05	4.75	2.67	2.35	16.72	13	18.41	15.57	15.32	8.71	7.00	4.98
3	5.26	4.67	5.86	5.04	4.25	3.64	2.89	3.48	11.39	10.26	12.80	11.99	10.36	7.36	1.50	1.22
4	9.19	11.11	10.58	12.84	6.98	5.94	2.56	3.50	14.06	12.13	15.73	14.52	12.55	8.19	6.00	3.95
5	5.13	5.79	5.66	6.56	4.38	3.82	1.89	2.37	10.44	8.04	11.71	8.84	9.38	6.75	3.33	3.20
6	5.69	6.71	6.16	7.24	5.06	5.68	2.33	2.45	7.69	7.32	7.78	6.22	7.97	8.68	2.67	1.97
7	6.42	7.58	7.10	8.41	5.51	5.62	1.56	1.74	9.57	8.90	11.05	10.31	8.25	6.56	2.33	2.07
8	3.40	4.02	3.80	4.42	2.69	3.07	2.22	2.11	9.86	8.51	10.87	8.85	8.95	8.15	5.17	4.45
9	6.86	7.57	7.59	8.39	5.52	5.53	5.00	5.12	5.41	5.50	6.51	6.61	4.08	3.27	4.67	5.01
10	6.35	9.70	7.34	11.30	4.65	4.99	2.78	5.17	9.99	6.96	10.45	7.53	9.64	6.28	6.83	5.15
Group B_2	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
1	1.43	1.67	1.45	1.32	1.52	2.55	1.00	0.32	12.82	13.78	13.85	15.47	11.21	8.95	7.82	7.05
2	9.06	10.16	10.17	11.45	7.67	6.75	4.60	5.38	14.84	11.53	15.60	11.59	13.33	11.31	12.45	11.88
3	5.93	5.27	6.61	5.72	5.08	3.75	3.15	4.28	12.10	12.03	13.17	12.47	11.49	11.04	2.91	5.68
4	10.81	12.77	11.79	13.09	10.82	13.04	3.20	5.01	13.84	17.95	15.79	20.48	11.30	9.09	2.45	4.03
5	2.03	2.20	2.23	2.50	1.85	1.42	1.05	1.10	10.42	9.57	11.23	10.20	10.51	7.51	1.18	2.75
6	7.81	7.79	8.57	8.67	7.62	5.45	2.45	3.25	6.80	6.42	7.33	6.72	6.67	5.72	1.55	2.16
7	7.66	7.55	8.33	8.16	7.75	6.06	2.25	3.68	8.34	9.74	9.31	10.36	7.53	8.27	1.00	1.26
8	4.61	5.36	5.06	5.90	4.48	4.20	1.45	2.06	6.67	6.99	7.53	7.34	5.05	4.75	3.64	8.83
9	9.65	10.28	10.70	11.09	9.40	8.46	2.20	3.64	5.19	5.57	5.93	6.19	4.14	3.45	1.27	1.56
10	7.40	8.20	7.99	8.55	8.02	7.71	0.95	1.84	8.86	7.85	9.53	8.41	8.95	5.95	1.18	2.14

Note. M = mean, SD = standard deviation, S1 = semester 1 course, S2 = semester 2 course, Group B_1: cohort^{s1} = semester 1 cohort (n = 262), CHEM2401(n = 172), CHEM2911 (n = 81), CHEM2915 (n = 9), cohort^{s2}= semester 2 cohort (n = 179), CHEM2402 (n = 97), CHEM2912 (n = 76) and CHEM2915 (n = 6). Group $B_{2:}$ cohort$_1$= semester 1 cohort (n = 235), CHEM2401 (n = 155), CHEM2911 (n = 60), CHEM2915 (n = 20), cohort$_2$= semester 2 cohort (n = 174), CHEM2402 (n =120), CHEM2912 (n = 43), and CHEM2915 (n =11).

5.3.6 Online behavioural patterns

5.3.6.1 Distribution of online behavioural patterns

Students' interactions with the weekly online pre-learning material were analysed for Group B_1 and Group B_2 at a cohort level for each semester. As previously noted in Section 3.12, no weekly pre-learning materials are presented during the weeks in the semester in which the online in-semester tutorial quizzes take place (week 5 and week 10). For each group, the distribution of students' online behaviour across the six behavioural types was captured (see Table 5.1 for description of behavioural types). However, this was not possible for BP_5 (V) as no student is able to solely access the video without the quiz. As such, the value for this behavioural type across both groups and both semesters remained at zero. Distribution of online behavioural pattern for each the three intermediate chemistry courses and variation in individual behaviours throughout the course of each semester were not examined.

For Group B_1, the distribution of the online behavioural patterns varied across both semesters (see Figure 5.15 and Figure 5.16). The dominant behavioural pattern during semester 1 was BP_2 (Q > V) where the quiz was more frequently accessed when compared to the associated video. An average of 54% of students adopted this pattern throughout the semester. The remaining students were distributed across the other behavioural types, with 12% in BP_1 (Q), 13% in BP_3 (Q = V), 9% in BP_4 (V > Q) and 12% in BP_6 (N/A).

The dominant behavioural pattern during semester 2 was also BP_2, with an average of 79% of students adopting this type throughout this semester. The remaining students were distributed across the other behavioural types, with 2% in BP_1 and the rest approximately evenly distributed across BP_3, BP_4 and BP_6 ranging between 6-7%.

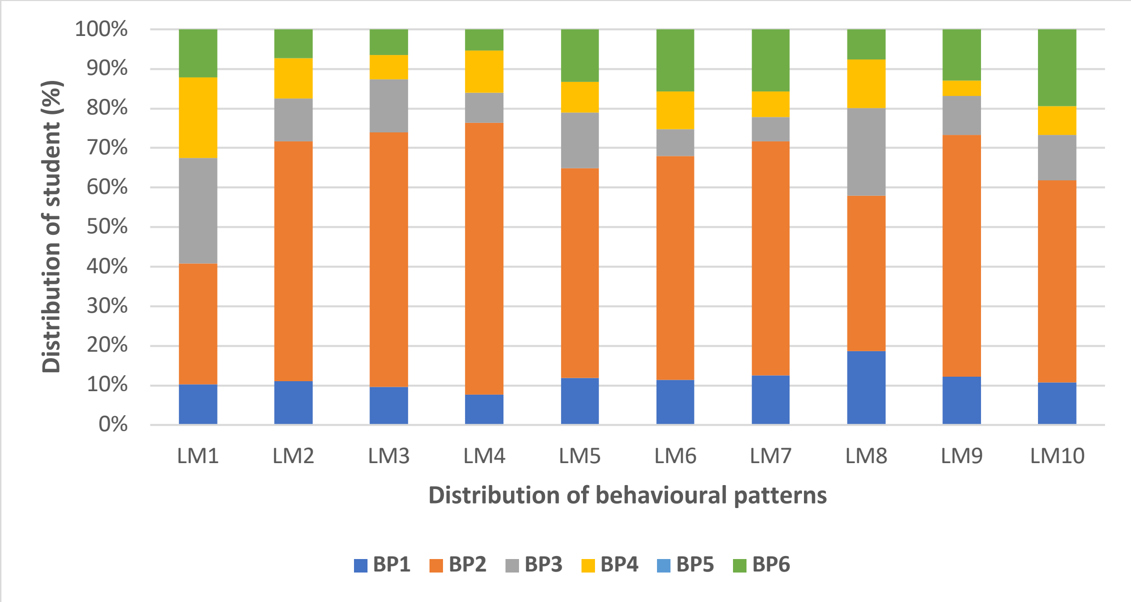

Figure 5.15. Distribution of online behavioural patterns across the pre-learning materials (LM) for Group B_1 semester 1 (n = 262).

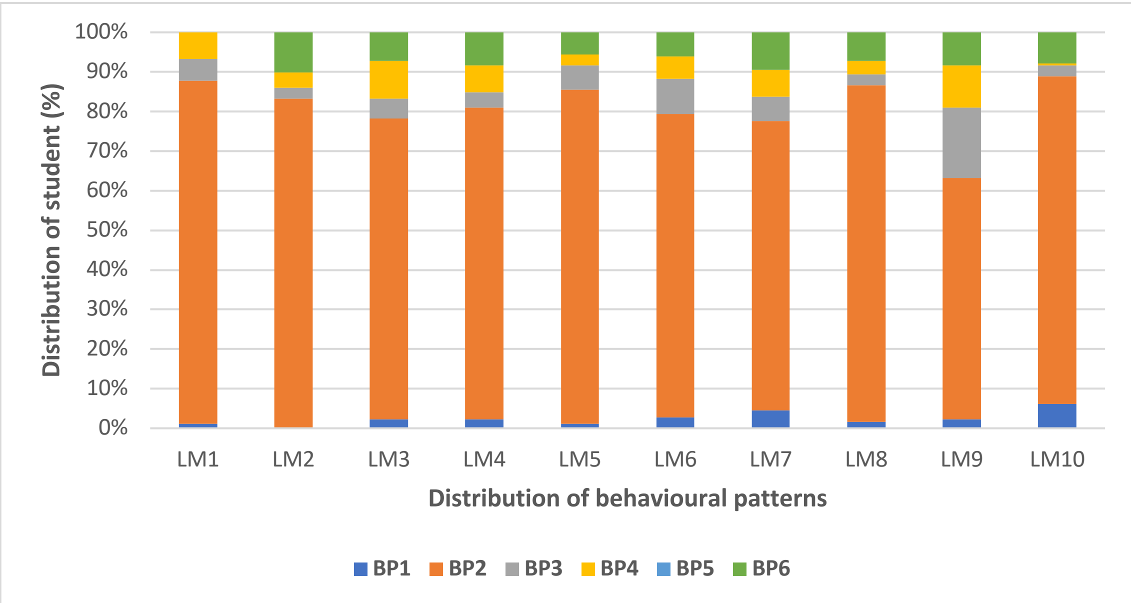

Figure 5.16. Distribution of online behavioural patterns across the pre-learning materials (LM) for Group B_1 semester 2 (n = 179).

Similar trends can be observed for Group B_2, with the distribution of the online behavioural patterns varying across both semesters (Figures 5.17 and Figure 5.18). The dominant behavioural pattern during semester 1 was BP_2. An average of 58% of students adopted this pattern throughout the semester. The remaining students were distributed across the other behavioural types, with 8% in BP_1, 14% in BP_3, 6% in BP_4 and 13% in BP_6. The dominant behavioural pattern during semester 2 was also BP_2, with an average of 71% of students adopting this type throughout this semester. The remaining students were distributed across the other behavioural types, with 3% in BP_1, 7% in BP_3 and BP_4 and 13% in BP_6.

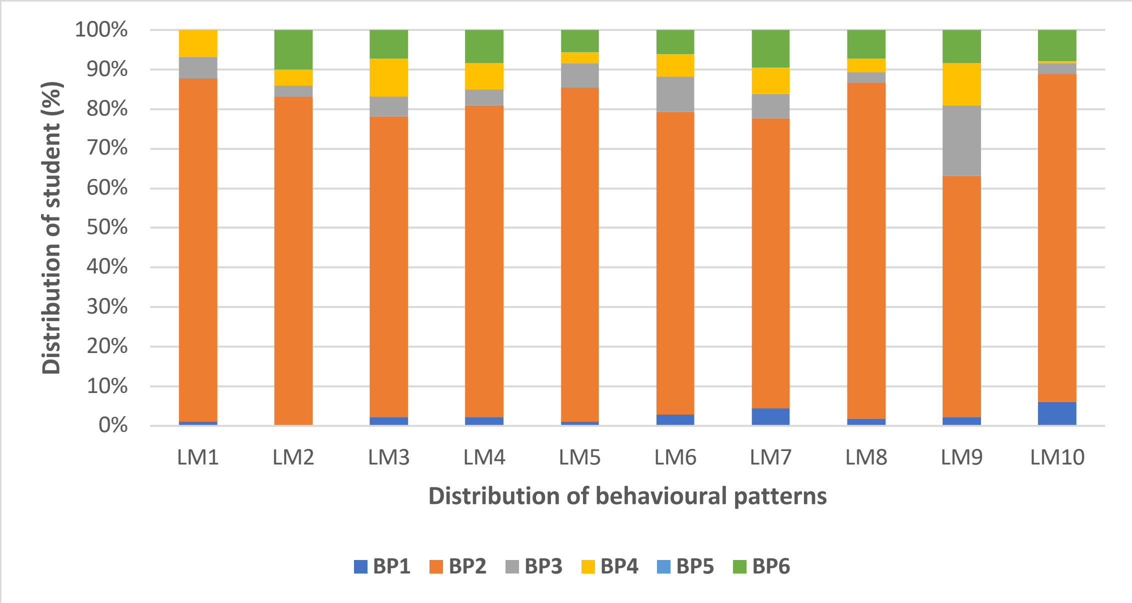

Figure 5.17. Distribution of online behavioural patterns across the pre-learning materials (LM) for Group B_2 semester 1 (n = 235).

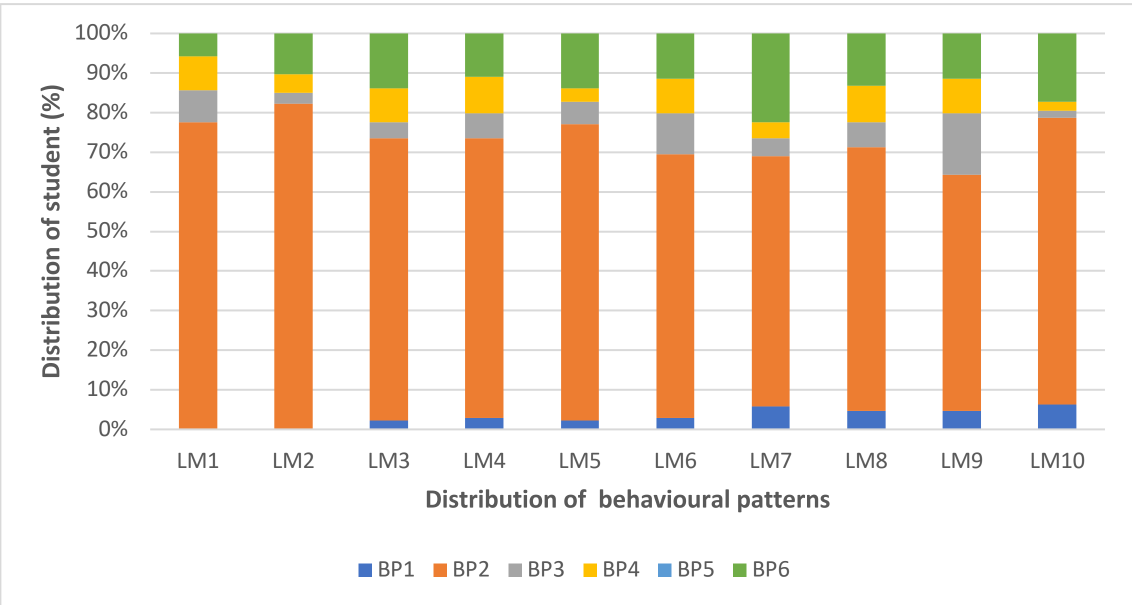

Figure 5.18. Distribution of online behavioural patterns across the pre-learning materials (LM) for Group B_2 semester 2 (n = 174).

5.3.6.2 Richness and Evenness of online behavioural patterns

The behavioural richness and evenness were analysed for Group B_1 and Group B_2 at a cohort level for each semester. The behavioural richness for Group B_1 remained relatively constant and was on average 2.66±0.21 for semester 1 and on average 2.43±0.15 for semester 2 (see Figure 5.19). This indicates that students were accessing the online material in a similar manner during semester 1 (slope = 0.007, F = 0.078, R^2 = 0.009, p > 0.05) and semester 2 (slope = 0.011, F = 0.470, R^2 = 0.055, p > 0.05).

The behavioural richness for Group B_2 remained relatively constant and was on average 2.72±0.22 for semester 1 and on average 2.61±0.13 for semester 2 (see Figure 5.19). This indicates that students were accessing the online pre-learning material in a similar manner during semester 1 (slope = 0.034, F = 2.254, R^2 = 0.220, p > 0.05) and semester 2 (slope = 0.023, F = 4.426, R^2 = 0.356, p > 0.05).

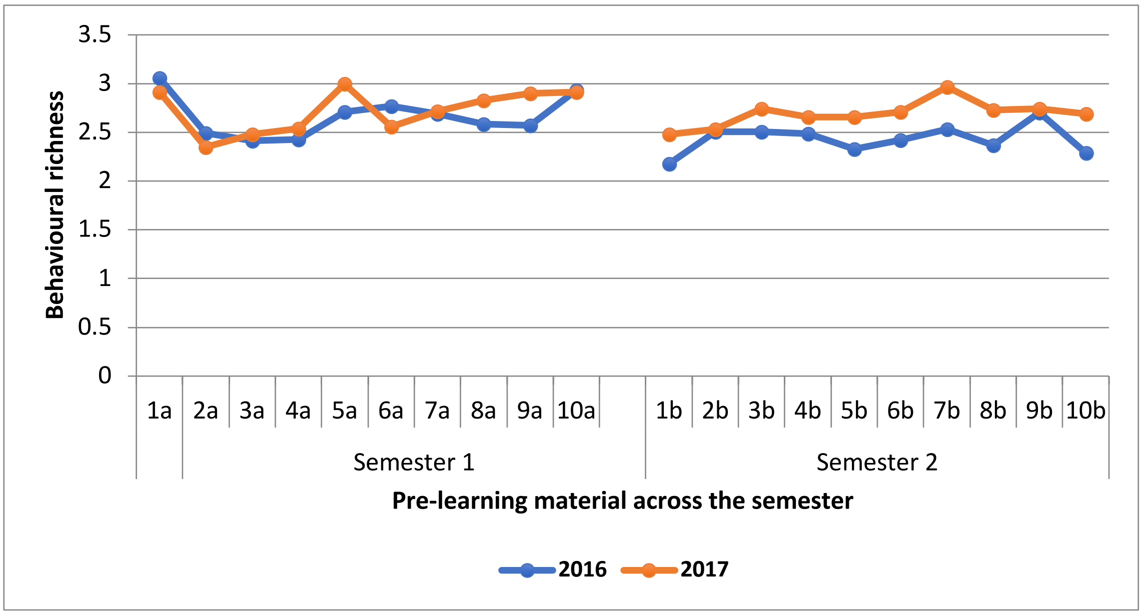

Figure 5.19. Behavioural richness for Group B_1 and Group B_2 across both semesters.

The behavioural evenness for Group B_1 remained relatively constant and was on average 0.23±0.03 for semester 1 and on average 0.15±0.04 for semester 2 (see Figure 5.20). Since this behavioural evenness value is low, it shows that there was one or few dominant behaviours in students access to the online pre-learning material during semester 1 (slope = 0.0002, F = 0.004, R^2 = 0.0005, p > 0.05) and semester 2 (slope = 0.005, F = 1.76, R^2 = 0.18, p > 0.05).

The behavioural evenness for Group B_2 remained relatively constant and was on average 0.20±0.05 for semester 1 and on average 0.18±0.03 for semester 2 (see Figure 5.20). Since this behavioural evenness value is low, it shows that there was one or few dominant behaviours in students access to the online pre-learning material during semester 1 (slope = 0.0003, F = 0.003, R^2 = 0.0004, $p > 0.05$) and semester 2 (slope = 0.007, F = 5.82, R^2 = 0.421, $p < 0.05$).

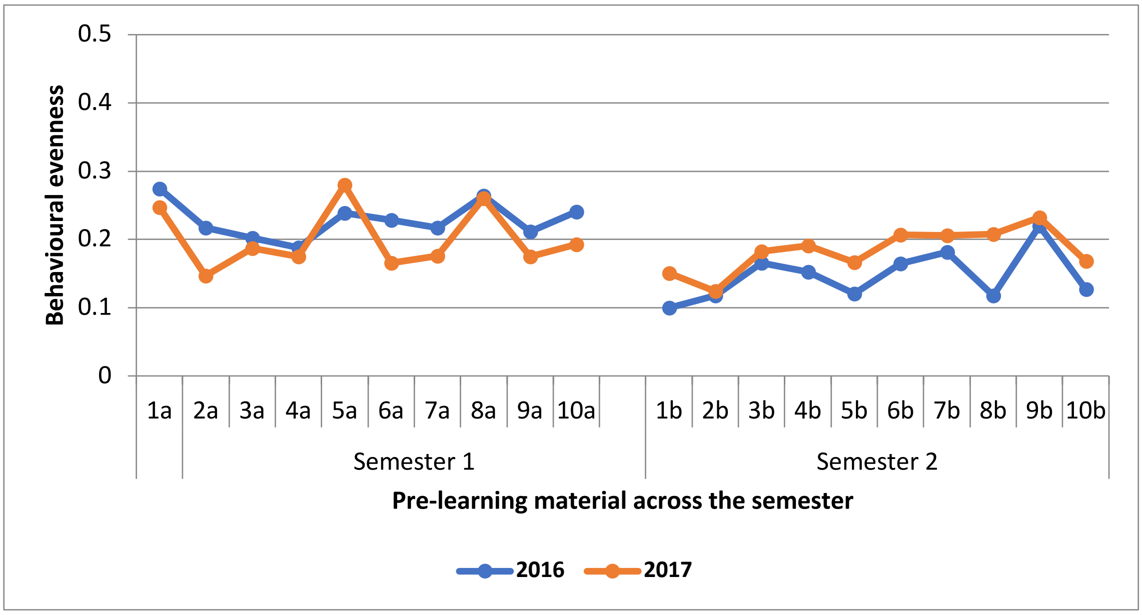

Figure 5.20. Behavioural evenness for Group B_1 and Group B_2 across both semesters.

5.3.7 Pre-learning videos effect on academic performance

5.3.7.1 Effect of viewing behaviour on academic performance

The students' behaviour with the videos and its effect on their academic performance were analysed for Group B_1 and Group B_2 at a cohort level for each semester. As previously noted, the same online pre-learning materials (see Section 3.12) and the same course assessment items (see Section 3.10) were used across the three levels of intermediate chemistry courses. Therefore, data was aggregated for the three levels of intermediate chemistry courses to improve the statistical power of the analysis. Table 5.10 shows the cohort academic performance across various course assessments for both Group B_1 and Group B_2 for each semester.

Table 5.10. Academic performance of the cohort across various course assessment items.

	Group B_1				Group B_2			
	Semester 1		Semester 2		Semester 1		Semester 2	
	n = 262		*n* = 179		*n* = 235		*n* = 174	
	M	SD	M	SD	M	SD	M	SD
Online pre-learning quizzes	87.03	10.67	79.08	18.63	85.72	11.11	84.76	11.06
Online in-semester quizzes	72.24	19.50	74.25	23.56	73.06	15.87	66.25	22.77
End of semester examination	54.95	21.26	63.37	24.71	62.17	20.52	57.91	20.78
Overall theory course performance	46.23	14.11	49.78	14.96	50.41	13.09	46.06	14.67

Note. M = mean performance, SD = standard deviation.

Students were then categorised into four groups according to their viewing behaviours over the course of the semester; those that viewed all ten videos (V_{All}), greater or equal to five videos ($V_{\geq 5}$), less than five videos ($V_{<5}$) and those that did not view any videos (V_N).

Sections 5.3.7.2 to Section 5.3.7.5 report on one-way ANOVA analyses carried out to investigate the academic performance of students across the various behavioural viewing groups. To compare the academic performance of the various viewing groups the measures used were the scores for: the online pre-learning quizzes, in-semester quizzes, end of semester examination and overall theory course performance (combines the scores for the online pre-learning quizzes, in-semester quizzes, and end of semester examination). The data will report on four behavioural viewing groups for semester 1 and three behavioural viewing groups for semester 2 (as there were no students in the V_N group) for both Groups B_1 and B_2. Table 5.11 provides a summary of the results obtained from the one-way ANOVA analyses and post-hoc Tukey's *t*-test by identifying the significant differences in academic performance observed on a cohort level among the behavioural viewing pairs for Groups B_1 and B_2 across each semester. Appendix J (Tables J.1 to Table J.8) provides more details regarding the individual one-way ANOVA analyses and post-hoc Tukey's *t*-test comparison of the academic performance of the cohort across the various measures for both groups across the semesters.

5.3.7.2 Effect of viewing behaviour on the online pre-learning quizzes

5.3.7.2.1 Viewing behaviour effect on the online pre-learning quizzes for Group B_1

A one-way ANOVA showed a significant difference in the online pre-learning quizzes among the four behavioural viewing groups for semester 1 [$F_{3,258} = 40.031$, $p < 0.001$] and between the three behavioural viewing groups for semester 2 [$F_{2,176} = 10.848$, $p < 0.001$] (see Table J.1). A post-hoc Tukey's *t*-test indicated significant differences in the mean score for the pre-learning quiz among four behavioural viewing pairs for semester 1 and three behavioural viewing pairs for semester 2.

5.3.7.2.2 Viewing behaviour effect on the online pre-learning quizzes for Group B_2

A one-way ANOVA showed a significant difference in the online pre-learning quizzes among the four behavioural viewing groups for semester 1 [$F_{3,231} = 66.391$, $p < 0.001$] and between the three behavioural viewing groups for semester 2 [$F_{2,171} = 89.751$, $p < 0.001$] (see Table J.2). A post-hoc Tukey's *t*-test indicated significant differences in the mean score for the pre-learning quiz among five behavioural viewing pairs for semester 1 and three behavioural viewing pairs for semester 2.

5.3.7.3 Effect of viewing behaviour on the online in-semester quizzes

5.3.7.3.1 Viewing behaviour effect on the online in-semester quizzes for Group B_1

A one-way ANOVA showed no significant difference in the online in-semester quiz performance among the four behavioural viewing groups for semester 1 [$F_{3,258} = 1.598$, $p = 0.190$], however, a significant difference was observed between the three behavioural viewing groups for semester 2 [$F_{2,176} = 21.744$, $p < 0.001$] (see Table J.3). A post-hoc Tukey's *t*-test indicated significant differences in the mean score for the in-semester quizzes among all three behavioural viewing groups for semester 2.

5.3.7.3.2 Viewing behaviour effect on the online in-semester quizzes for Group B_2

A one-way ANOVA showed no significant difference in the online in-semester quiz performance among the four behavioural viewing groups for semester 1 [$F_{3,231} = 0.914$, $p = 0.435$], however, a significant difference was observed between the three behavioural viewing groups for semester 2 [$F_{2,176} = 21.744$, $p < 0.001$] (see Table J.4). A post-hoc Tukey's *t*-test indicated significant differences in the mean score for the in-semester quizzes between one behavioural viewing pair for semester 2.

5.3.7.4 Effect of viewing behaviour on the end of semester examination

5.3.7.4.1 Effect of viewing behaviour on the end of semester examination for Group B_1

A one-way ANOVA showed no significant difference in the end of semester examination score among the four behavioural viewing groups for semester 1 [$F_{3,258} = 2.532$, $p = 0.058$], however, a significant difference was observed between the three behavioural viewing groups for semester 2 [$F_{2,176} = 7.837$, $p < 0.001$] (see Table J.5). A post-hoc Tukey's *t*-test indicated significant differences in the mean score for the end of semester between one behavioural viewing pair for semester 2.

5.3.7.4.2 Effect of viewing behaviour on the end of semester examination for Group B_2

A one-way ANOVA showed a significant difference in the end of semester examination score among the four behavioural viewing groups for semester 1 [$F_{3,231} = 2.855$, $p = 0.038$], however, no significant difference was observed between the three behavioural viewing groups for semester 2 [$F_{2,166} = 1.292$, $p = 0.277$] (see Table J.6). A post-hoc Tukey's *t*-test indicated significant differences in the mean score for the end of semester between one behavioural viewing pair for semester 1.

5.3.7.5 Effect of viewing behaviour on the overall theory course performance

5.3.7.5.1 Effect of viewing behaviour on the theory course performance for Group B_1

A one-way ANOVA showed a significant difference in the overall theory course performance among the four behavioural viewing groups for semester 1 [$F_{3,258} = 4.352$, $p = 0.005$] and among the three behavioural viewing groups for semester 2 [$F_{2,176} = 11.766$, $p < 0.001$] (see Table J.7). A post-hoc Tukey's *t*-test indicated significant differences in the mean score for the overall theory course performance between one behavioural viewing pair for semester 1 and semester 2.

5.3.7.5.2 Effect of viewing behaviour on the theory course performance for Group B_2

A one-way ANOVA showed a significant difference in the overall theory course performance among the four behavioural viewing groups for semester 1 [$F_{3,231} = 4.413$, $p = 0.005$] and among the three behavioural viewing groups for semester 2 [$F_{2,171} = 5.246$, $p = 0.006$] (see table J.8). A post-hoc Tukey's *t*-test indicated significant differences in the mean score for the overall theory course performance between two behavioural viewing pairs for semester 1 and semester 2.

Table 5.11. Behavioural viewing pairs showing significant differences in academic performance at a cohort level according to a one-way ANOVA analyses and post-hoc Tukey's *t*-test results.

	Group B_1		Group B_2	
	Semester 1	Semester 2	Semester 1	Semester 2
Online pre-learning quizzes	• V_{All} and $V_{<5}$ • V_{All} and $V_{\geq5}$ • V_{All} and $V_{<N}$ • $V_{<5}$ and $V_{\geq5}$	• V_{All} and $V_{<5}$ • V_{All} and $V_{\geq5}$ • $V_{<5}$ and $V_{\geq5}$	• V_{All} and $V_{<5}$ • V_{All} and $V_{\geq5}$ • V_{All} and $V_{<N}$ • $V_{<5}$ and $V_{\geq5}$ • V_N and $V_{<5}$	• V_{All} and $V_{<5}$ • V_{All} and $V_{\geq5}$ • $V_{<5}$ and $V_{\geq5}$
Online in-semester quizzes	• NS	• V_{All} and $V_{<5}$ • V_{All} and $V_{\geq5}$ • $V_{<5}$ and $V_{\geq5}$	• NS	• V_{All} and $V_{\geq5}$
End of semester examination	• NS	• V_{All} and $V_{\geq5}$	• V_{All} and $V_{<5}$	• NS
Overall course performance	• V_{All} and $V_{\geq5}$	• V_{All} and $V_{<5}$	• V_{All} and $V_{<5}$ • V_{All} and $V_{\geq5}$	• V_{All} and $V_{\geq5}$

Note. NS = no significance, V_{All} = all videos, $V_{<5}$ = less than five videos, $V_{\geq5}$ = greater or equal to five videos and V_N = no video views.

5.3.8 Pre-learning quiz effect on academic performance

5.3.8.1 Effect of pre-learning quiz interaction on academic performance

The students' behaviour with the pre-learning quizzes and its effect on their academic performance were analysed for Group B_1 and Group B_2 at a cohort level for each semester. Students were categorised into three groups according to their quiz interaction over the course of the semester; those that attempted all ten videos (Q_{All}), less than five quizzes ($Q_{<5}$), greater or equal to five quizzes ($Q_{\geq5}$). For Group B_1 and Group B_2 across both semesters there were no students that did not attempt all quizzes (Q_N).

Sections 5.3.8.2 to Section 5.3.8.5 report on one-way ANOVA analyses carried out to investigate the academic performance of students across the various behavioural quiz groups. To compare the academic performance of the various behavioural quiz groups the measures used were the scores for: the online pre-learning quizzes, in-semester quizzes, end of semester examination and overall theory course performance (combines the scores for the online pre-learning quizzes, in-semester quizzes, and end of semester examination). The data will report on three behavioural quiz groups for Groups B_1 and B_2 across both semesters. Table 5.12 provides a summary of the results obtained from the one-way ANOVA analyses and post-hoc

Tukey's *t*-test by identifying the significant differences in academic performance observed on a cohort level among the behavioural quiz pairs for Groups B_1 and B_2 across each semester. Appendix K (Tables K.1 to Table K.8) provides more details regarding the individual one-way ANOVA analyses and post-hoc Tukey's *t*-test comparison of the academic performance of the cohort across the various measures for both groups across the semesters.

5.3.8.2 Effect of pre-learning quiz interaction on the pre-learning quizzes

5.3.8.2.1 Effect of pre-learning quiz interaction on the pre-learning quizzes performance in Group B_1

A one-way ANOVA showed a significant difference in the online pre-learning quiz score for semester 1 [$F_{2,259} = 295.97$, $p < 0.001$] but no significant difference was observed for semester 2 [$F_{2,176} = 3.236$, $p = 0.042$] among the three behavioural quiz groups (see Table K.1). A post-hoc Tukey's *t*-test indicated a significant difference in the mean score of the online pre-learning quiz among all behavioural quiz pairs for semester 1.

5.3.8.2.2 Effect of pre-learning quiz interaction on the pre-learning quizzes performance in Group B_2

A one-way ANOVA showed a significant difference in the online pre-learning quiz score for semester 1 [$F_{2,232} = 637.08$, $p < 0.001$], however, no significant difference was observed for semester 2 [$F_{2,171} = 99.45$, $p = 0.048$] among the three behavioural quiz groups (see Table K.2). A post-hoc Tukey's *t*-test indicated a significant difference in the mean score of the online pre-learning quiz among all behavioural quiz pairs for semester 1.

5.3.8.3 Effect of pre-learning quiz interaction on the online in-semester quizzes

5.3.8.3.1 Effect of pre-learning quiz interaction on the online in-semester quizzes in Group B_1

A one-way ANOVA showed a significant difference in the online in-semester quiz for both semester 1 [$F_{2,259} = 14.687$, $p < 0.001$] and semester 2 [$F_{2,176} = 13.00$, $p < 0.001$] among all three behavioural groups (see Table K.3). A post-hoc Tukey's *t*-test indicated a significant difference in the mean score for the in-semester quizzes among all behavioural quiz pairs for both semesters.

5.3.8.3.2 Effect of pre-learning quiz interaction on the online in-semester quizzes in Group B_2

A one-way ANOVA showed a significant difference in the online in-semester quiz for both semester 1 [$F_{2,232} = 3.562$, $p = 0.030$] and semester 2 [$F_{2,171} = 5.638$, $p = 0.004$] among the three behavioural quiz groups (see Table K.4). A post-hoc Tukey's *t*-test indicated significant differences in the mean score for in-semester quiz among one behavioural quiz pair for semester 1 and two behavioural quiz pairs for semester 2.

5.3.8.4 Effect of pre-learning quiz interaction on the end of semester examination

5.3.8.4.1 Effect of pre-learning quiz interaction on the end of semester examination in Group B_1

A one-way ANOVA showed a significant difference in the end of semester examination performance for semester 1 [$F_{2,259} = 17.248$, $p < 0.001$] and semester 2 [$F_{2,176} = 6.126$, $p = 0.003$] among the three behavioural quiz groups (see Table K.5). A post-hoc Tukey's *t*-test indicated significant differences in the mean end of semester examination performance among all three behavioural quiz groups for semester 1 and one behavioural quiz pair for semester 2.

5.3.8.4.2 Effect of pre-learning quiz interaction on the end of semester examination in Group B_2

A one-way ANOVA showed a significant difference in the end of semester examination performance for semester 1 [$F_{2,232} = 8.817$, $p < 0.001$], however, no significant difference was observed for semester 2 [$F_{2,176} = 0.891$, $p = 0.412$] among the three behavioural quiz groups (see Table K.6). A post-hoc Tukey's *t*-test indicated a significant difference in the mean end of semester examination performance between one behavioural quiz pair for semester 1.

5.3.8.5 Effect of pre-learning quiz interaction on the overall theory course performance

5.3.8.5.1 Effect of pre-learning quiz interaction on the overall theory course performance in Group B_1

A one-way ANOVA showed a significant difference in the overall theory course performance for semester 1 [$F_{2,259} = 30.436$, $p < 0.001$] and semester 2 [$F_{2,176} = 11.766$, $p < 0.001$] among all three behavioural quiz groups (see Table K.7). A post-hoc Tukey's *t*-test indicated that there was a significant difference in the overall theory course performance among all three behavioural quiz groups for semester 1 and one behavioural quiz pair for semester 2.

5.3.8.5.2 Effect of pre-learning quiz interaction on the overall theory course performance in Group B_2

A one-way ANOVA showed a significant difference in the overall theory course performance for semester 1 [$F_{2,232} = 13.239$, $p < 0.001$] and semester 2 [$F_{2,171} = 4.049$, $p = 0.019$] among the three behavioural groups (see Table K.8). A post-hoc Tukey's *t*-test indicated that there was a significant difference in the overall mean academic performance between one behavioural quiz group for both semesters.

Table 5.12. Behavioural quiz pairs showing significant differences in academic performance at a cohort level according to a one-way ANOVA analyses and post-hoc Tukey's *t*-test results.

	Group B_1		Group B_2	
	Semester 1	Semester 2	Semester 1	Semester 2
Online pre-learning quizzes	• Q_{All} and $Q_{<5}$ • Q_{All} and $Q_{\geq 5}$ • $Q_{<5}$ and $Q_{\geq 5}$	• NS	• Q_{All} and $Q_{<5}$ • Q_{All} and $Q_{\geq 5}$ • $Q_{<5}$ and $Q_{\geq 5}$	• NS
Online in-semester quizzes	• Q_{All} and $Q_{<5}$ • Q_{All} and $Q_{\geq 5}$ • $Q_{<5}$ and $Q_{\geq 5}$	• Q_{All} and $Q_{<5}$ • Q_{All} and $Q_{\geq 5}$ • $Q_{<5}$ and $Q_{\geq 5}$	• Q_{All} and $Q_{<5}$	• Q_{All} and $Q_{<5}$ • Q_{All} and $Q_{\geq 5}$
End of semester examination	• Q_{All} and $Q_{<5}$ • Q_{All} and $Q_{\geq 5}$ • $Q_{<5}$ and $Q_{\geq 5}$	• Q_{All} and $Q_{<5}$	• Q_{All} and $Q_{<5}$	• NS
Overall course performance	• Q_{All} and $Q_{<5}$ • Q_{All} and $Q_{\geq 5}$ • $Q_{<5}$ and $Q_{\geq 5}$	• Q_{All} and $Q_{<5}$	• Q_{All} and $Q_{<5}$	• Q_{All} and $Q_{\geq 5}$

Note. NS = no significance, Q_{All} = all quizzes, $Q_{<5}$ = less than five quizzes, $Q_{\geq 5}$ = greater or equal to five quizzes.

5.3.9 Online behavioural pattern and effect on academic performance

The students' weekly quiz performance across varying behavioural patterns was analysed for Group B_1 and Group B_2 at a cohort level for each semester. For each semester, the mean score across the total number of quiz attempts was used instead of the final quiz score as this score is more indicative of students' interactions with the pre-learning materials. Due to the mastery nature of the pre-learning quizzes most of the students would attain a final score of ten irrespective of how many attempts they may have had. A student making many attempts to master the pre-learning materials may have a lower mean score in the pre-learning quizzes. As such, the mean score provides a better indication of students' interaction when comparing it to their number of attempts. The number of students in each behavioural pattern category varied on a weekly basis (see Section 5.3.6).

Across both semesters, students in Group B_1 that displayed BP_3 and BP_4 consistently achieved a higher mean score in the pre-learning quizzes relative to the remaining behavioural types (see Figure 5.21 and Figure 5.22). These students had a higher score in the pre-learning quizzes than the overall mean quiz score throughout the semester. However, varying trends were observed for the remaining behavioural types. In semester 1, students that displayed BP_2 achieved the lowest mean scores in the pre-learning quizzes whereas in semester 2 students that displayed BP_1 achieved the lowest mean scores in the pre-learning quizzes throughout the weeks.

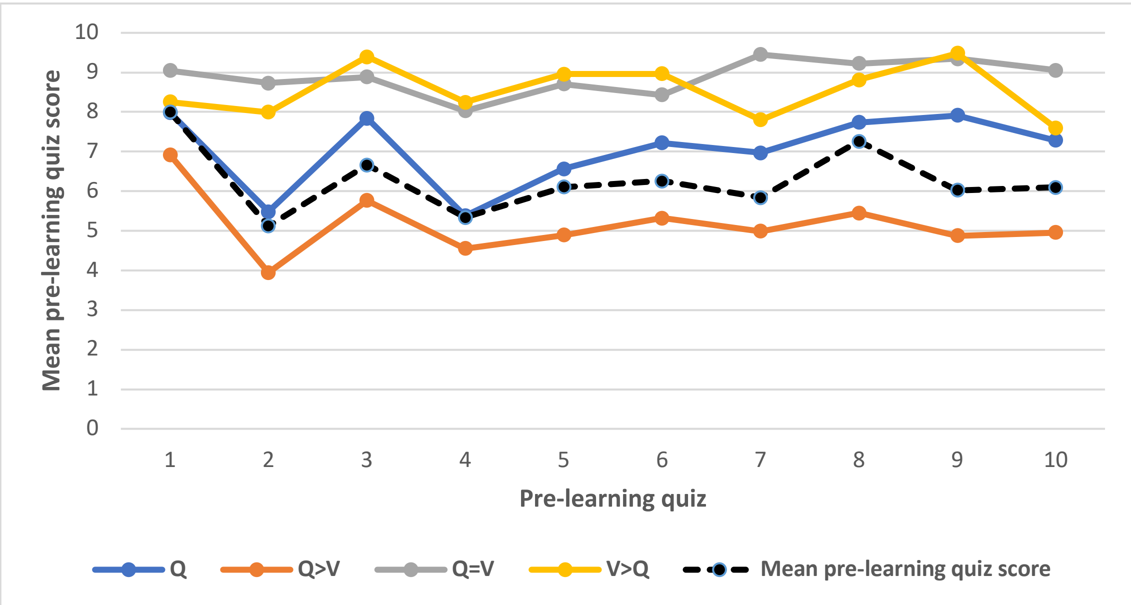

Figure 5.21. Mean weekly quiz score across the various behavioural pattern types for Group B_1 semester 1.

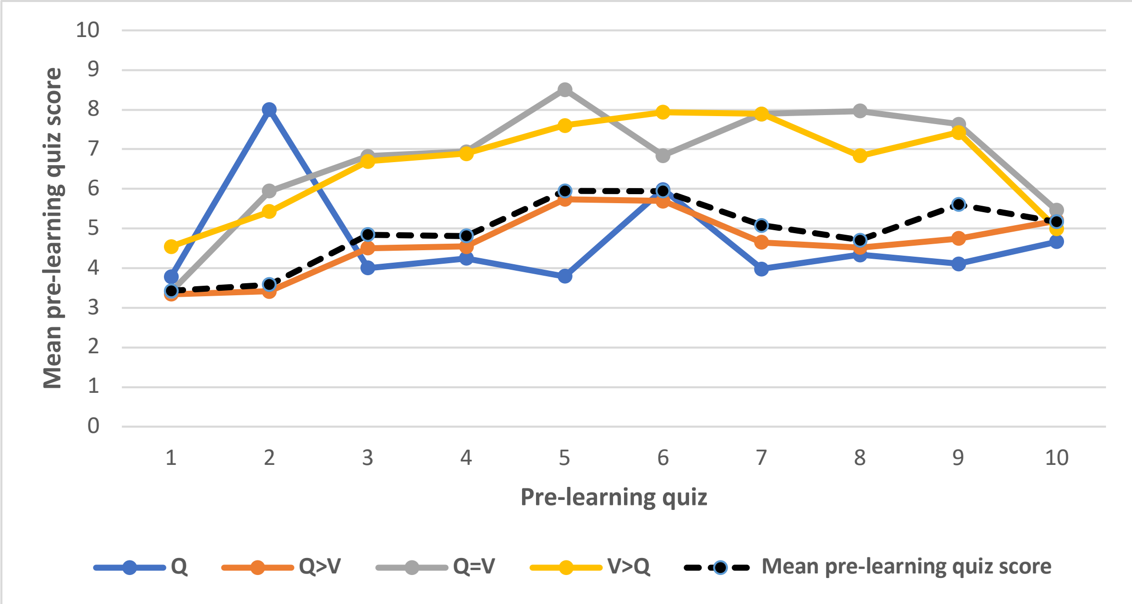

Figure 5.22. Mean weekly quiz score across the various behavioural types for Group B_1 semester 2.

Across both semesters, students in Group B_2 that displayed BP_3 and BP_4 consistently achieved a higher mean score in the pre-learning quizzes relative to the remaining behavioural types (see Figure 5.23 and Figure 5.24). These students had a higher mean score in the pre-learning quizzes than the overall mean quiz score throughout the semester. However, varying trends were observed for the reimaging behavioural types. In semester 1, students that displayed BP_1 and BP_2 achieved lowest mean scores in the pre-learning quizzes whereas in semester 2, students that consistently displayed BP_2 achieved the lowest mean scores in the pre-learning quizzes throughout the weeks.

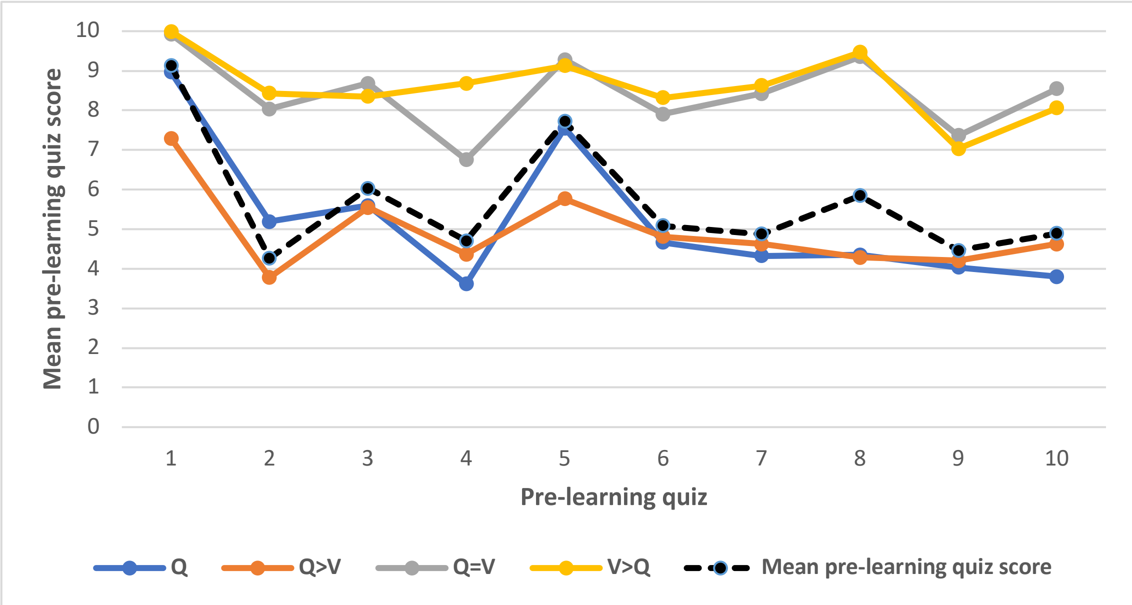

Figure 5.23. Mean weekly quiz score across the various behavioural types for Group B_2 semester 1.

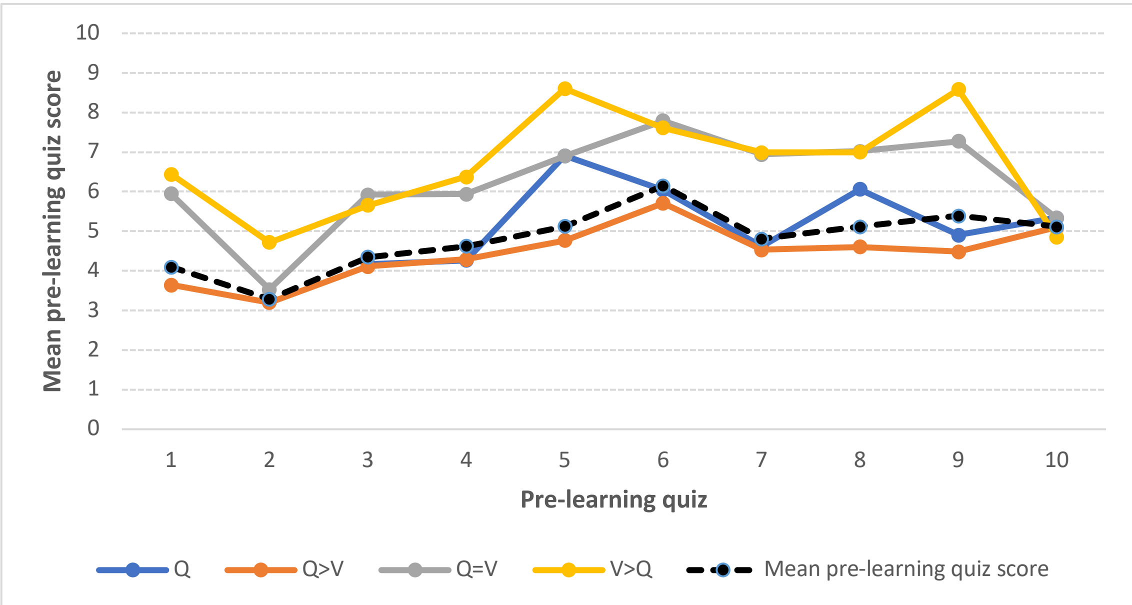

Figure 5.24. Mean weekly quiz score across the various behavioural types for Group B_2 semester 2.

5.3.9.1 Difference in academic performance of varying behavioural pattern groups on a cohort level

The following section report on one-way ANOVA analyses carried out to investigate the academic performance of students across the behavioural pattern groups. To compare the academic performance of the various behavioural patterns groups the measures used were the scores for: the online pre-learning quizzes, in-semester quizzes, end of semester examination and overall theory course performance (combines the scores for the online pre-learning quizzes, in-semester quizzes, and end of semester examination). Table 5.13 provides a summary of the results obtained from the one-way ANOVA analyses and post-hoc Tukey's *t*-test by identifying the significant differences in academic performance on a cohort level observed among the behavioural pattern pairs for Groups B_1 and B_2 across each semester. Appendix L (Tables L.1 to Table L.4) provides more details regarding the individual one-way ANOVA analyses and post-hoc Tukey's *t*-test comparison of the cohort level academic performance across the various measures for both groups across the semesters.

5.3.9.1.1 Academic performance of behavioural pattern groups in Group B_1

A one-way ANOVA showed a significant difference in the overall pre-learning quiz score [$F_{4,257} = 78.447$, $p < 0.001$], the end of semester examination [$F_{4,257} = 8.839$, $p < 0.001$] and overall theory course performance [$F_{4,257} = 12.925$, $p < 0.001$] for semester 1 among the behavioural pattern groups (see Table L.1). A post-hoc Tukey's *t*-test indicated that there were significant differences in the overall mean scores for the pre-learning quiz and overall theory course performance among five behavioural pattern pairs. A post-hoc Tukey's *t*-test also indicated that there were significant differences in the mean score for the end of semester examination among three behavioural pattern pairs.

A one-way ANOVA showed a significant difference in the overall pre-learning quiz score [$F_{3,175} = 10.852$, $p < 0.001$], however, there was no significant difference in the end of semester examination [$F_{3,175} = 0.389$, $p = 0.761$] and the overall course performance for semester 2 [$F_{3,175} = 0.852$, $p = 0.467$] among the behavioural pattern groups (see Table L.2). A post-hoc Tukey's *t*-test indicated that there were significant differences in the mean score for the pre-learning quiz among two behavioural pattern pairs.

5.3.9.1.2 Academic performance of behavioural pattern groups in Group B_2

A one-way ANOVA showed a significant difference in the overall pre-learning quiz score [$F_{4,230}$ = 114.312, p < 0.001], however, no significant difference was observed in the end of semester examination [$F_{4,230}$ = 1.530, p = 0.194] and the overall theory course performance among the behavioural pattern groups for semester 1 [$F_{3,175}$ = 0.849, p = 0.496] (see Table L.3). Post-hoc Tukey's *t*-test indicated that there were significant differences in the mean score for the pre-learning quiz among six behavioural pattern pairs.

A one-way ANOVA showed a significant difference in the overall pre-learning quiz score among all behavioural pattern groups for semester 2 [$F_{3,170}$ = 46.632, p < 0.001], however, no significant difference was observed in the end of semester examination [$F_{3,175}$ = 2.757, p = 0.05] and the overall theory course performance among the behavioural pattern groups for semester 2 [$F_{3,175}$ = 0.328, p = 0.021] (see Table L.4). A post-hoc Tukey's *t*-test indicated that were significant differences in the mean score for the pre-learning quiz among five behavioural pattern pairs.

Table 5.13. Behavioural pattern pairs showing significant differences in academic performance at a cohort level according to a one-way ANOVA analyses and post-hoc Tukey's *t*-test results.

	Group B_1		Group B_2	
	Semester 1	Semester 2	Semester 1	Semester 2
Online pre-learning quizzes	• BP_1 and BP_6 • BP_2 and BP_4 • BP_2 and BP_6 • BP_3 and BP_6 • BP_4 and BP_6	• BP_2 and BP_6 • BP_3 and BP_6	• BP_1 and BP_6 • BP_2 and BP_3 • BP_2 and BP_4 • BP_2 and BP_6 • BP_3 and BP_6 • BP_4 and BP_6	• BP_2 and BP_3 • BP_2 and BP_4 • BP_2 and BP_6 • BP_3 and BP_4 • BP_3 and BP_6
End of semester examination	• BP_1 and BP_6 • BP_2 and BP_6 • BP_3 and BP_6	• NS	• NS	• NS
Overall course performance	• BP_1 and BP_4 • BP_1 and BP_6 • BP_2 and BP_6 • BP_3 and BP_6 • BP_4 and BP_6	• NS	• NS	• NS

Note. NS = no significance, BP = behaviour pattern where BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_5 = V and BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

5.3.9.2 Difference in academic performance of varying behavioural pattern groups on a course level

The following section report on one-way ANOVA analyses carried out to investigate the academic performance of students across the behavioural pattern groups. To compare the academic performance of the various behavioural pattern groups the measures used were the scores for: the online pre-learning quizzes, in-semester quizzes, end of semester examination and overall theory course performance (combines the scores for the online pre-learning quizzes, in-semester quizzes, and end of semester examination). Table 5.14 provides a summary of the results obtained from the one-way ANOVA analyses and post-hoc Tukey's *t*-test by identifying the significant differences in academic performance on a course level observed among the behavioural pattern pairs for Groups B_1 and B_2 across each semester. Appendix M (Tables M.1 to Table M.9) provides more details regarding the individual one-way ANOVA analyses and post-hoc Tukey's *t*-test comparison of the course level academic performance across the various measures for both groups across the semesters.

5.3.9.2.1 Mainstream course analysis of varying behavioural pattern for Group B_1

For CHEM2401, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{4,167} = 39.639$, $p < 0.001$], end of semester examination [$F_{4,167} = 10.376$, $p < 0.001$] and overall theory course performance [$F_{4,167} = 15.069$, $p < 0.001$] among the behavioural pattern groups for semester 1 (see Table M.1). Post-hoc Tukey's *t*-test revealed that there were significant differences in the mean scores for the pre-learning quiz, end of semester examination and overall theory course performance among five behavioural pattern pairs.

For CHEM2402, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{3,93} = 20.822$, $p < 0.001$], however, no significant difference was observed in the end of semester examination and overall theory course performance among the behavioural pattern groups for semester 2 (See Table M.2). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean score for the pre-learning quiz among four behavioural pattern pairs.

5.3.9.2.2 Advanced course analysis of varying behavioural pattern for Group B_1

For CHEM2911, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{4,85} = 72.212$, $p < 0.001$], however, no significant difference was observed in the end of semester examination and overall theory course performance among the behavioural pattern groups for semester 1 (see Table M.3). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean score for the pre-learning quiz among four behavioural pattern pairs.

For CHEM2912, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{3,72} = 9.004$, $p < 0.001$], however, no significant difference in the end of semester examination and overall theory course performance among the behavioural pattern groups for semester 2 (See Table M.4). A post-hoc Tukey's *t*-test was not carried out as fewer cases ($n < 4$) were present in several behavioural pattern group.

5.3.9.2.3 SSP course analysis of varying behavioural pattern for Group B_1

For CHEM2915, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{4,85} = 72.212$, $p < 0.001$], however, no significant difference was observed in the end of semester examination and overall theory course performance among the behavioural pattern groups for semester 1 (See Table M.5). A post-hoc Tukey's *t*-test was not carried out as fewer cases ($n < 3$) were present in several behavioural pattern group.

For CHEM2916, a one-way ANOVA showed no significant difference in the pre-learning quiz score, end of semester examination and overall theory course performance among the behavioural pattern groups for semester 2 (See Table M.4).

5.3.9.2.4 Mainstream course analysis of varying behavioural pattern for Group B_2

For CHEM2401, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{4,150} = 40.670$, $p < 0.001$] and overall theory course performance [$F_{4,150} = 3.746$, $p < 0.001$], however, no significant difference was observed in the end of semester examination among the behavioural pattern groups for semester 1 (See Table M.6). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean scores for the pre-learning quiz among five behavioural pairs and between one behavioural pair in the overall theory course performance for semester 1.

For CHEM2402, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{4,15} = 25.799$, $p < 0.001$] and overall theory course performance [$F_{4,15} = 19.499$, $p < 0.001$], however, no significant difference was observed in the end of semester examination among the behavioural pattern groups for semester 2 (See Table M.7). A post-hoc Tukey's *t*-

test revealed that there were significant differences in the mean scores for the pre-learning quiz among four behavioural pattern pairs and between two behavioural pairs in the overall theory course performance for semester 2.

5.3.9.2.5 Advanced course analysis of varying behavioural pattern for Group B_2

For CHEM2911, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{2,57} = 7.592$, $p < 0.001$] and overall theory course performance [$F_{2,57} = 3.662$, $p < 0.001$], however, no significant difference was observed in the end of semester examination among the behavioural pattern groups for semester 1 (See Table M.8). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean scores for the pre-learning quiz among two behavioural pattern pairs and between one pair in the overall mean course performance for semester 1.

For CHEM2912, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{3,39} = 41.930$, $p < 0.001$], however, no significant difference was observed in the end of semester examination and overall theory course performance among the behavioural pattern groups for semester 2 (See Table M.9). A post-hoc Tukey's *t*-test was not carried out as fewer cases ($n < 4$) were present in several behavioural pattern group.

5.3.9.2.6 SSP course analysis of varying behavioural pattern for Group B_2

For CHEM2915, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{4,15} = 25.799$, $p < 0.001$], however, no significant difference was observed in the end of semester examination and overall theory course performance among the behavioural pattern groups for semester 1 [$F_{4,15} = 25.799$, $p < 0.001$] (See Table M.8). A post-hoc Tukey's *t*-test was not carried out as fewer cases ($n < 3$) were present in several behavioural pattern group.

For CHEM2916, a one-way ANOVA showed no significant difference in the pre-learning quiz score, end of semester examination and overall theory course performance among the behavioural pattern groups for semester 2.

Table 5.14. Behavioural pattern pairs showing significant differences in academic performance at a course level according to a one-way ANOVA analyses and post-hoc Tukey's *t*-test results.

	Semester 1			Semester 2		
	CHEM2401	CHEM2911	CHEM2915	CHEM2402	CHEM2912	CHEM2916
Group B_1 Online pre-learning quizzes	• BP_1 and BP_6 • BP_2 and BP_4 • BP_2 and BP_6 • BP_3 and BP_6 • BP_4 and BP_6	• BP_1 and BP_2 • BP_1 and BP_6 • BP_2 and BP_6 • BP_3 and BP_6 • BP_4 and BP_6	• BP_1 and BP_4 • BP_1 and BP_6 • BP_2 and BP_6 • BP_3 and BP_6 • BP_4 and BP_6	• BP_2 and BP_4 • BP_2 and BP_6 • BP_3 and BP_4 • BP_3 and BP_6	• NS	• NS
End of semester examination	• BP_1 and BP_6 • BP_2 and BP_6 • BP_3 and BP_6 • BP_4 and BP_6	• NS	• NS	• BP_2 and BP_3 • BP_2 and BP_4 • BP_2 and BP_6 • BP_3 and BP_4 • BP_3 and BP_6	• NS	• NS
Overall course performance	• NS	• NS	• NS	• NS	• NS	• NS
Group B_2 Online pre-learning quizzes	• BP_1 and BP_6 • BP_2 and BP_3 • BP_2 and BP_6 • BP_3 and BP_6 • BP_4 and BP_6	• BP_1 and BP_2 • BP_1 and BP_3	• NS	• BP_2 and BP_4 • BP_2 and BP_6 • BP_3 and BP_6 • BP_4 and BP_6	• NS	• NS
End of semester examination	• NS	• NS	• NS	• NS	• NS	• NS
Overall course performance	• BP_2 and BP_6	• BP_1 and BP_3	• NS	• BP_2 and BP_6 • BP_3 and BP_6	• NS	• NS

Note. NS = No significance, BP = behaviour pattern where BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_5 = V and BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

5.3.10 Difference in academic performance of varying behavioural patterns across engagement groups

The following section report on one-way ANOVA analyses carried out to investigate the academic performance of students across the behavioural pattern groups according to their engagement level. Students were categorised into three groups according to their level of engagement (as identified in Chapter 4). To compare the academic performance of the various behavioural pattern groups the measures used were the scores for: the online pre-learning quizzes, in-semester quizzes, end of semester examination and overall theory course performance (combines the scores for the online pre-learning quizzes, in-semester quizzes, and end of semester examination). Table 5.15 and Table 5.16 provides a summary of the results obtained from the one-way ANOVA analyses and post-hoc Tukey's *t*-test by identifying the significant differences in academic performance observed on a cohort level among the behavioural pattern pairs based on the three engagement levels for Groups B_1 and Groups B_2 across both semesters respectively. Appendix N (Tables N.1 to N.9) provides more details regarding the individual one-way ANOVA analyses and post-hoc Tukey's *t*-test comparison of the cohort level academic performance across the various measures for both groups across the semesters.

5.3.10.1 Difference in academic performance of varying behavioural patterns across engagement groups for Group B_1 semester 1

For the low engaged group, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{4,83} = 49.475$, $p < 0.001$], end of semester examination [$F_{4,83} = 5.410$, $p < 0.001$], and overall course performance [$F_{4,83} = 7.668$, $p < 0.001$] among the behavioural pattern groups (see Table N.1). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean scores for the pre-learning quiz among five behavioural pairs, between two behavioural pairs in the end of semester examination and among three behavioural pairs in the overall theory course performance.

For the moderately engaged group, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{4,82} = 20.955$, $p < 0.001$], however, no significant difference was observed in the end of semester examination [$F_{4,82} = 0.755$, $p = 0.558$], and overall theory course performance [$F_{4,82} = 0.850$, $p = 0.498$] among the behavioural pattern groups (see Table N.2). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean score for the pre-learning quiz among six behavioural pairs.

For the highly engaged group, a one-way ANOVA showed no significant difference in the pre-learning quiz score [$F_{3,83} = 0.868$, $p = 0.461$], end of semester examination [$F_{3,83} = 0.915$, $p = 0.437$], and overall theory course performance [$F_{3,83} = 1.025$, $p = 0.386$], among the behavioural pattern groups (see Table N.3).

5.3.10.2 Difference in academic performance of varying behavioural patterns across engagement groups for Group B_1 semester 2

For the low engaged group, a one-way ANOVA showed no significant difference in the pre-learning quiz score [$F_{2,33} = 2.475$, $p = 0.120$], however, a significant difference was observed in the end of semester examination [$F_{2,33} = 1.410$, $p < 0.001$], and overall theory course performance [$F_{2,33} = 1.320$, $p < 0.001$] among the behavioural pattern groups (see Table N.4). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean scores for the end of semester examination and overall theory course performance among two behavioural pairs.

For the moderately engaged group, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{3,99} = 9.851$, $p < 0.001$], however, no significant difference was observed in the end of semester examination [$F_{3,99} = 0.092$, $p = 0.964$], and overall theory course performance [$F_{3,99} = 0.410$, $p = 0.746$] among the behavioural pattern groups (see Table N.5). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean score for the pre-learning quiz among three behavioural pairs.

For the highly engaged group, a one-way ANOVA showed no significant difference in the pre-learning quiz score [$F_{3,33} = 2.038$, $p = 0.128$], end of semester examination [$F_{3,33} = 0.312$, $p = 0.817$], and overall theory course performance [$F_{3,33} = 0.339$, $p = 0.797$], among the behavioural pattern groups (see Table N.6).

Table 5.15. Behavioural pattern pairs showing significant differences in academic performance across engagement groups at a cohort level according to a one-way ANOVA analyses and post-hoc Tukey's *t*-test results for Group B_1.

	Semester 1			Semester 2		
	Low engagement	Moderate engagement	High engagement	Low engagement	Moderate engagement	High engagement
Online pre-learning quizzes	• BP_1 and BP_4 • BP_1 and BP_4 • BP_2 and BP_4 • BP_2 and BP_6 • BP_3 and BP_6	• BP_1 and BP_6 • BP_2 and BP_3 • BP_2 and BP_4 • BP_2 and BP_6 • BP_3 and BP_6 • BP_4 and BP_6	• NS	• NS	• BP_2 and BP_6 • BP_3 and BP_6 • BP_4 and BP_6	• NS
End of semester examination	• BP_1 and BP_6 • BP_2 and BP_6	• NS	• NS	• BP_2 and BP_3 • BP_2 and BP_4	• NS	• NS
Overall course performance	• BP_1 and BP_6 • BP_2 and BP_6 • BP_3 and BP_6	• NS	• NS	• BP_2 and BP_3 • BP_2 and BP_4	• NS	• NS

Note. NS = no significance, BP = behaviour pattern where $BP_2 = Q > V$, $BP_3 = Q = V$, $BP_4 = Q < V$, $BP_5 = V$ and $BP_6 = N/A$, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

5.3.10.3 Difference in academic performance of varying behavioural patterns across engagement groups for Group B_2 semester 1

For the low engaged group, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{5,76} = 68.452$, $p < 0.001$], however, no significant difference was observed in the end of semester examination [$F_{5,76} = 1.763$, $p = 0.131$], and overall theory course performance [$F_{5,76} = 1.564$, $p = 0.180$] among the behavioural pattern groups (see Table N.7). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean score for the pre-learning quiz among seven behavioural pairs.

For the moderately engaged group, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{3,75} = 10.448$, $p < 0.001$], however, no significant difference was observed in the end of semester examination [$F_{3,75} = 1.362$, $p = 0.261$], and overall theory course performance [$F_{3,75} = 1.359$, $p = 0.262$] among the behavioural pattern groups (see Table N.8). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean score for the pre-learning quiz among one behavioural pair.

For the highly engaged group, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{3,70} = 7.507$, $p < 0.001$], however, no significant difference was observed in the end of semester examination [$F_{3,70} = 1.612$, $p = 0.194$], and overall theory course performance [$F_{3,70} = 1.261$, $p = 0.295$] among the behavioural pattern groups (see Table N.8). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean score for the pre-learning quiz among one behavioural pair.

5.3.10.4 Difference in academic performance of varying behavioural patterns across engagement groups for Group B_2 semester 2

For the low engaged group, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{3,56} = 16.426$, $p < 0.001$], however, no significant difference was observed in the end of semester examination [$F_{3,56} = 0.999$, $p = 0.400$], and overall theory course performance [$F_{3,56} = 0.586$, $p = 0.627$] among the behavioural pattern groups (see Table N.9). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean score for the pre-learning quiz among three behavioural pairs.

For the moderately engaged group, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{2,57} = 19.533$, $p < 0.001$], however, no significant difference was observed in the end of semester examination [$F_{2,57} = 0.675$, $p = 0.513$], and overall theory course performance [$F_{2,57} = 2.751$, $p = 0.072$] among the behavioural pattern groups (see Table N.9). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean score for the pre-learning quiz among one behavioural pair.

For the highly engaged group, a one-way ANOVA showed a significant difference in the pre-learning quiz score [$F_{2,51} = 15.222$, $p < 0.001$], however, no significant difference was observed in the end of semester examination [$F_{2,48} = 1.057$, $p = 0.356$], and overall theory course performance [$F_{2,51} = 1.425$, $p = 0.250$] among the behavioural pattern groups (see Table N.9). A post-hoc Tukey's *t*-test revealed that there were significant differences in the mean score for the pre-learning quiz among two behavioural pairs.

Table 5.16. Behavioural pattern pairs showing significant differences in academic performance across engagement groups at a cohort level according to a one-way ANOVA analyses and post-hoc Tukey's *t*-test results for Group B_2.

	Semester 1			Semester 2		
	Low engagement	Moderate engagement	High engagement	Low engagement	Moderate engagement	High engagement
Online pre-learning quizzes	• BP_1 and BP_3 • BP_1 and BP_4 • BP_1 and BP_6 • BP_2 and BP_3 • BP_2 and BP_4 • BP_2 and BP_6 • BP_3 and BP_6	• BP_2 and BP_3	• BP_2 and BP_3	• BP_1 and BP_2 • BP_2 and BP_3 • BP_2 and BP_4	• BP_2 and BP_3	• BP_2 and BP_3 • BP_2 and BP_4
End of semester examination	• NS	• NS	• NS	• NS	• NS	• NS
Overall course performance	• NS	• NS	• NS	• NS	• NS	• NS

Note. BP = behaviour pattern where BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_5 = V and BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

5.3.11 Students' perception of the online component of a partially flipped learning model

Students' perception of the online pre-learning materials was only gathered for Group B_2, as ethics approval was granted too late to collect data for Group B_1. The questionnaire included five closed-ended questions, five Likert-type questions, and three-open ended questions (see Appendix E).

Two of the closed-ended questions asked whether students accessed each of the pre-learning materials. The three follow up closed-ended questions prompted the students to select from a list of reasons provided the one(s) which best described their approach. Most of the students indicated the reasons for watching the videos were to improve their academic performance in the quizzes (n = 48) and to aid in their conceptual understanding of chemistry (n = 39). The main reasons identified for completing the quizzes were that the quizzes contributed to their marks (n = 47), clarified concepts (n = 40), were perceived to be easy marks (n = 35) or were a good revision tool (n = 33).

Responses to the Likert type questions (see Figure 5.25) provided further details regarding students' perceptions of the online pre-learning materials. Students generally reported a positive perception of the pre-learning materials, with most students (n = 31) reporting a cohesive link between the pre-learning materials. Students' responses also indicated they value the pre-learning videos as a tool to introduce and provide foundational knowledge needed for the in-class sessions (n = 16). Other students (n = 20) also suggested that the quizzes enhanced their overall learning experience.

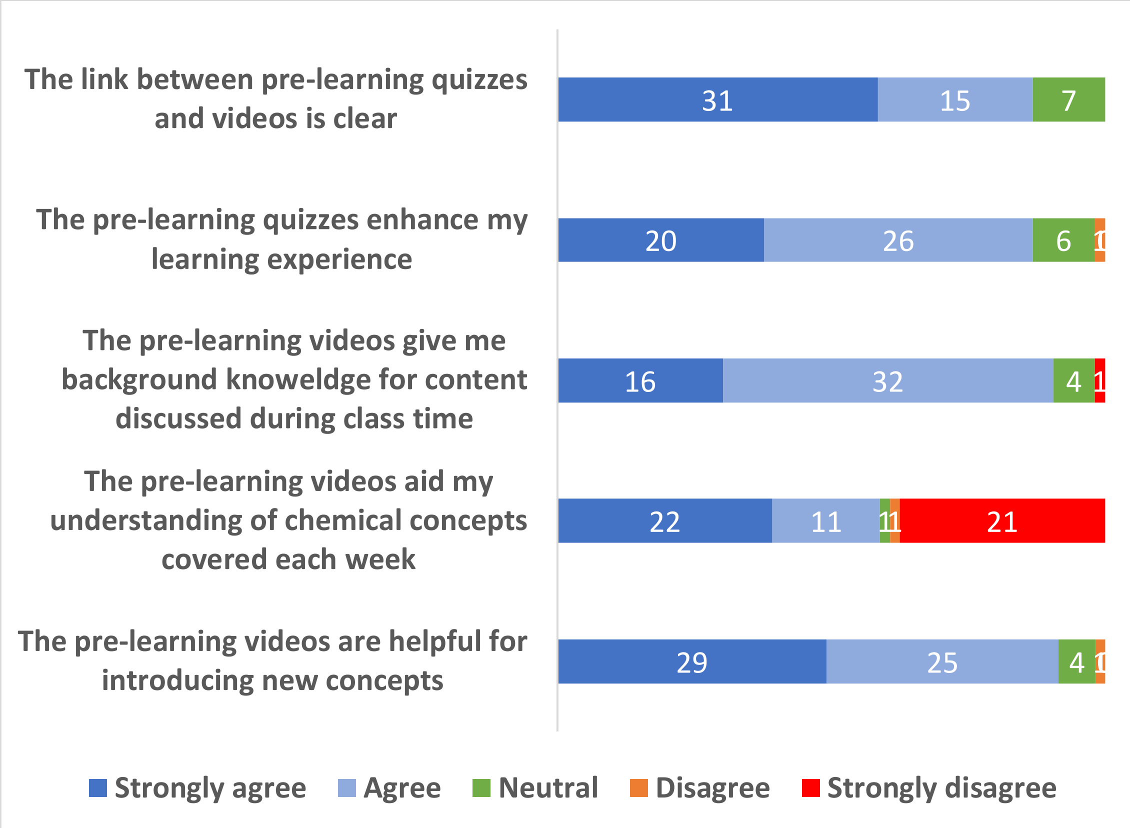

Figure 5.25. Likert scale questionnaire responses regarding students' perception of the online pre-learning materials.

Responses to the three open-ended questions provided valuable insight about the design features students valued in each of the videos and quizzes with proposed improvements to further enhance their learning experience (see Table 5.17).

Table 5.17. Students' open-ended responses about design features and proposed improvements for future implementation.

Valued design features of pre-learning materials	Proposed improvements
Clarity of explanations in the video (*n* = 10)	Interactive video features (*n* = 4)
Flexible access (*n* = 4)	Additional videos for harder concepts (*n* = 4)
Visual support in the video (*n* = 7)	Hints and prompts during the quiz (*n* = 2)
Mastery nature of quiz (*n* = 8)	Variation of question types (*n* = 2)
Variety of challenging questions (*n* = 2)	Harder application quizzes (*n* = 3)
Auto-generated quiz feedback (*n* = 9)	
Foundational background knowledge (*n* = 5)	
Revision tool (*n* = 3)	
Cohesive links between resources and in-class session (*n* = 12)	

Students appreciated the flexible nature of accessing each of the pre-learning materials at a pace that was suitable for their learning needs. Students also found the pre-learning materials to be a valuable learning tool providing foundational background knowledge needed for the course as well as a revision tool. Furthermore, students found the explanations presented during the pre-learning videos to be clear and easy to follow. They also appreciated the cohesive link between each concept presented during the video and the seamless transition from one concept to another. Another design feature that students valued was the visual support embedded in the videos with a specific reference made to the diagrams used during the explanation for the curly arrows used in organic reaction mechanism. In addition, students valued the mastery nature of the quizzes, specifically the ability to repeat them multiple times.

A few students (n = 2) reported that the pre-learning quizzes provided them with a variety of questions to practise their understanding of the concepts presented during the videos. Another commonly identified design feature that students valued was the auto-generated quiz feedback, which was provided to students irrespective of whether they answered the questions correctly or incorrectly. In general, students appreciated the cohesive links between the pre-learning materials and suggested that they provided them with sufficient foundational knowledge needed to engage during the in-class sessions.

The open-ended responses to the third question focused on students proposing features that can improve the design of the online pre-learning materials. The students' responses suggested the inclusion of additional interactive features in the videos, including additional visual aids. Several suggestions were made to improve the students' learning experience with the pre-learning quizzes; for instance, embedding hints and prompts to guide students in selecting the correct answer, the inclusion of a variation of question types and modifying the level of difficulty of the questions to further support the development of their procedural and conceptual understanding of chemistry.

5.4 Discussion

5.4.1 Students' interaction with the pre-learning videos and pre-learning quizzes in a partially flipped learning environment

This chapter further explored the significance of the online pre-learning materials by examining how varying degrees of interaction with the pre-learning videos and pre-learning quizzes may impact academic performance. Current research supports the value of online pre-learning materials as a gateway to facilitate learning during the in-class sessions (Lee & Choi, 2019). The online pre-learning materials give students the opportunity to self-pace their learning in a reflective manner whilst acquiring initial exposure to conceptual knowledge prior to the in-class sessions (Abeysekera & Dawson, 2015; Long et al., 2019; Naibert et al., 2020). This chapter contributes to the current research by exploring the direct effect of the online pre-learning materials (Beatty et al., 2019; Dazo et al., 2016; Lee & Choi, 2019; Long et al., 2019) as current studies have predominately examined the holistic impact of the flipped learning model on students' learning experience and academic performance (O'Flaherty &Philips, 2015).

Initial analysis comparing cohort level data for Group B_1 and Group B_2 revealed that the degree students interacted with the videos and quizzes varied widely across each week. Some overall trends, however, were observed across both groups. The cohort data revealed that the number of videos accessed, and quizzes accessed in semester 2 were higher when compared to semester 1. When comparing the distribution of video-viewing patterns, students generally tended to view them multiple times. Further analysis was carried out on a course level with the data showing varying trends regarding access to the videos and quizzes. Semester 1 data for Group B_1 revealed that students in the mainstream course accessed the videos more frequently than those in the advanced and SSP courses. Video views in semester 2 were evenly distributed with students in the mainstream and advanced courses accessing the videos more frequently than those in the SSP course. The number of video views was more consistent across both semesters for Group B_2. Students in the mainstream courses and in the advanced courses accessed the videos more frequently than those in the SSP course. When comparing students' interaction with the quizzes, similar trends were observed across both groups with students in the mainstream courses accessing the pre-learning quizzes more frequently than those in the advanced and SSP courses.

The observed results may in part be attributed to the nature of the chemistry concepts delivered in each semester, with semester 1 focusing predominately on organic chemistry and semester 2 focusing on inorganic chemistry (see Table 3.7 for full topic descriptions). Historically and as observed in Group B_1 and Group B_2, the failure rates are higher for semester 2, when compared to semester 1. Intermediate chemistry courses in semester 1 reinforce and build on chemistry knowledge acquired in junior chemistry courses. Lower levels of video-viewing and quiz access might be due to students' previous familiarity with the chemistry concepts. In contrast, students have had limited exposure to inorganic chemistry in junior chemistry courses and therefore are less familiar with these concepts. This reduced familiarity might be an underlying factor for the higher levels of video-viewing and quiz access observed during the second semester.

Beatty et al. (2019) propose that variability in video-viewing trend may be related to how valuable students perceive the videos to be for their learning and the extent it may benefit them academically. This is evident in the mixed reviews gathered from students' comments were some students (n = 22) strongly perceived the pre-learning videos to aid their understanding of weekly chemical concepts covered during the in-class session whereas other students (n = 21) did not perceive them to be as valuable. The students that appreciated the pre-learning videos as a valuable learning tool for understanding concepts addressed during the in-class session may have accessed them more frequently than the remaining students. Beatty et al. (2019) proposed that video-viewing behaviours may be encouraged in several ways: (1) deliver important information at the beginning of the video, (2) access key concepts directly from the video, (3) embed interactive component such as a quiz and (4) selection of videos based on individual learning needs. O'Flaherty and Philips (2015) further expanded on this and suggested that the desired behavioural pattern may be encouraged by designing the pre-learning materials in an interactive manner, with formative feedback and content that is cohesively linked to the in-class materials. Subsequent sections will explore students' perception of learning in a partially flipped learning format and suggest reasons behind students' interactions with each of the pre-learning materials. Chapter 6 will further explore how students' self-identified approach of learning may influence their displayed behavioural pattern.

5.4.2 The effect of students' interaction with the pre-learning videos and pre-learning quizzes on their academic performance

This chapter extends the research on flipped learning as it provides empirical evidence to measure the direct effect of various video-viewing patterns on students' performance in the associated pre-learning quizzes. The cohort data for Group B_1 and Group B_2 were consistent; the most significant improvements were noted for students that viewed the video once compared to those that did not view the video. Further analysis revealed no clear trend when comparing the performance of students that watched the video once versus multiple times. It was hypothesised that students' proficiency level with the specific weekly concept may influence their adopted video-viewing pattern. However, it was not feasible to examine this.

Dazo et al. (2016) indicated that video-viewing behaviours are a binary measure in that they only detect whether a student has accessed the pre-learning video instead of the length of them viewing it and the quality of their video-viewing pattern. Future research is warranted to identify the reasons behind students' preference for displaying a particular video-viewing pattern and to gain insight about why significant differences were detected for specific weeks in which students either viewed videos just once or multiple times. Research examining the format of the pre-learning videos might also extend the explanations behind the observed variation in the students' level of interactions and its impact on their academic performance. Despite this, the results obtained reinforce the valuable effect of viewing the videos in providing students with the foundational knowledge needed for not only the in-class session but also to successfully complete the pre-learning quizzes.

To further examine the relationship between students' behavioural pattern and their academic performance, it was essential to analyse the degree of their interaction (none, partially, or fully) with the ten weekly pre-learning materials: videos and quizzes. The data revealed a positive association between changes in the degree of students' interaction with the materials and their academic performance across both Group B_1 and Group B_2. The most pronounced differences in performance were observed for students that interacted with all the assigned videos and quizzes over the course of a semester, when compared to those that either partially or did not interact with the pre-learning materials. A recent study analysing the impact of pre-learning materials on students' academic performance also revealed a positive correlation, and the strength of this correlation was almost twice when compared to the effect of the in-class learning component on learning outcomes (Lee & Choi, 2019). While similar findings are reported in this thesis, it should be noted that the online pre-learning materials reported in Lee and Choi (2019) only consisted of five pre-learning videos and reading materials were assigned for the remaining weeks of the semester. It was also not clear which specific features of the pre-learning materials contributed to the observed improvements in academic performance as instead the overall impact of the online component was measured. This differs from the findings presented in this thesis, as higher levels of interactions with each of the pre-learning materials appeared to influence overall academic performance.

Further studies of how varying behavioural patterns of interactions with videos and quizzes affected academic performance (pre-learning quiz score, in-semester quiz score, and end of semester examination) were also carried out. The cohort data for Group B_1 and Group B_2

revealed that students who interacted with all the pre-learning materials performed significantly better in the pre-learning quiz than those that partially or did not interact with any of the pre-learning materials. The results revealed that interacting with all the pre-learning quizzes resulted in significant improvements in the in-semester quiz performance. The effect of video-viewing patterns on the in-semester quizzes varied, however, with significant improvements only observed in the second semester for both groups. The differences observed in the performance of the pre-learning quiz and in-semester quiz may be attributed to the instructional design of the partially flipped learning model. The pre-learning quizzes examined concepts directly delivered in the associated pre-learning videos. It was observed that students with higher viewership levels over the course of the semester performed significantly better than those with lower viewership levels. The in-semester quizzes assess concepts covered over several weeks and are not limited to content presented in the pre-learning videos and as viewership levels might not have strongly influenced students' performance in the in-semester quizzes. In addition, no clear trends were observed when comparing end of semester examination across both groups. The most pronounced differences were observed in semester 2 for Group B_1 and semester 1 for Group B_2 where students that interacted with all the pre-learning materials performed significantly better in the end of semester examination compared to those that either partially or did not interact with the pre-learning materials. While the pre-learning materials provide foundational knowledge needed for the in-class sessions where students actively engage in building their procedural and conceptual understanding of course content, it was not feasible to isolate the direct effect of each of the pre-learning materials on students' academic performance in the end of semester examination.

The findings presented in this chapter revealed that higher viewership levels have a direct impact on the pre-learning quiz score but not necessarily on in-semester quiz score and end of semester examination. Other studies have also revealed how varying viewership levels influenced academic performance. Beatty et al. (2019) explored the relationship between video-viewing and academic performance in three exams and overall score between high performing and low performing students. There was a clear trend in video-viewing pattern where high performing students consistently watched more videos when compared to low performing students. Although no strong relationship was observed between video-viewing and exam performance, the findings suggest that high achieving students tend to be more engaged with the pre-learning videos. Empirical evidence by Dazo et al. (2016) revealed that students who viewed all pre-learning videos performed better in the course studied. Their findings also revealed that ‘punctuality’, which they defined as a measure of *when* students initially interact with the pre-learning videos relative to the in-class session, significantly correlated with students’ academic performance. This is particularly valuable as it suggests that students who interacted with all the pre-learning videos as originally intended, that is in advance of the in-class sessions, performed significantly better. Notably, the design of their flipped learning model differed from the one reported on in this thesis in that the pre-learning material was comprised only of a series of weekly videos. Subsequent sections in this chapter will contribute to the field by exploring how varying behavioural patterns, specifically the frequency of access with the videos and quizzes, can influence academic performance.

This chapter also reported that higher levels of interactions with the pre-learning quizzes can positively impact students’ performance in the in-semester quiz score and end of semester examination. Although pre-learning quizzes have been incentivised by attributing a graded component to them, their significance extends beyond that as they serve as valuable ‘gateway’ check to assess students’ conceptual understanding prior to the in-class sessions (Naibert et al., 2020; O’Flaherty & Philips, 2015). The findings described in this thesis differ from those presented in a preliminary study by Lacher and Lewis (2014) where it was observed that completing the pre-leaning quizzes did not lead to significant improvements in students’ course grade. In that study, higher aptitude students were found to benefit more from having quizzes than lower aptitude students, as they were reported to usually be less inclined to watch the videos. However, having pre-learning quizzes would encourage students to access all the required pre-learning materials. It was suggested that the quizzes were not designed to facilitate deep learning and instead relied on simple factual recall based on the videos. In a follow up study, Lacher and Lewis (2015) showed improvement in the performance of students that tended to adopt a surface approach towards their learning. The subsequent chapter will explore how students of varying approaches to learning interact with the quizzes and the potential effect on their academic performance.

Although the use of learning analytics is widely used to capture interactions with videos, it is not feasible to distinguish between whether students merely opened the videos or watched them to completion. To overcome this in the future, weekly self-reported data from the students may be gathered to provide insight on their observed interactions with the videos. Naibert et al. (2020) categorised students’ behaviour with the pre-learning videos and classified students into one of these four modes of engagement: interactive, constructive, active, or passive engagement. It was revealed that as students become more engaged with the videos and shift from passive to interactive, there was an improvement in their academic performance. To further extend the findings from this chapter, future work may combine self-reported data alongside learning analytics to gain a more holistic understanding of how varying behavioural patterns with the pre-learning videos may influence various measures of academic performance in a partially flipped learning model.

5.4.3 Changes in students' behavioural patterns with the online pre-learning materials over the course of a semester

Initial analysis comparing cohort level interactions for Group B_1 and Group B_2 revealed that students altered their weekly behavioural pattern. This shift in behavioural pattern distribution is consistent with other studies that support the notion that students can flexibly vary their level of behavioural engagement with the pre-learning materials to suit their individual learning needs (Kloft et al., 2014; Ramsden, 2003; Yuan & Powell, 2013).

Further analysis revealed that students' behavioural richness and evenness remained relatively consistent over the course of the semester for Group B_1 and Group B_2. It was hypothesised that behavioural richness would decrease, and as such, students shift from rare behaviours to more common behaviours. The data, however, showed that BP_2 remained dominant over the course of a semester. The data also showed that a low evenness score, which suggests that one or few behaviours were dominant, in this case BP_2, was the dominant and most frequently accessed behavioural pattern. These findings differ to those observed by Brennan et al. (2019) where a decrease in the number of online behavioural patterns was noted over the course of the semester. Instead, from the behavioural patterns identified five were continuously displayed with relatively varying frequency levels with the dominant behaviour pattern observed to be BP_2. One potential reason for the observed difference may be related to the number of pre-learning activities. In Brennan et al. (2019), students' behavioural patterns were based on four learning activities, and this yielded a total of 64 behavioural patterns, whereas this study focused on two pre-learning activities and as such only six distinct behavioural patterns were possible. It may be argued that the higher the number of pre-learning activities the more variability in behavioural pattern.

Further analysis comparing behavioural richness and evenness across the two semesters revealed that BP_2 remained the dominant behavioural pattern across both semesters. This differs from Brennan et al. (2019) where a decrease in behavioural richness was observed suggesting that students shifted their behavioural pattern over time. It was also noted that behavioural evenness remained relatively constant but reflected several strong dominant behaviours with relatively equal distributions of students in each behavioural type. The differences between the reported findings in this study and Brennan et al. (2019) reinforce the notion that students' behaviour is a flexible phenomenon and may be influenced by the learning context (Kloft et al., 2014). It is worth noting that the findings discussed explored students' behavioural pattern in the chemistry courses in isolation from any other remaining courses in which they may have been enrolled. Behavioural patterns displayed in the chemistry courses may be related to other factors beyond the scope of this study, for instance their behaviours may be impacted by assessments in other courses. Adopting the Brennan et al. (2019) approach within a partially flipped learning model has practical implication as it provides valuable insight regarding the varying behavioural patterns present within a course with reference to the specific pre-learning materials embedded. In addition, it can detect which behavioural pattern is the most dominant. This may allow course instructors to intervene, if required, to encourage or inhibit certain behaviours. In a partially flipped learning model, the optimum behavioural pattern would be to encourage students to access both pre-learning materials, with a preference for accessing the videos before the quizzes. While BP_2 suggests that students accessed both pre-learning materials, it suggests that students accessed the quizzes more frequently than the videos. One potential factor that may have led to these observed results may be attributed to individual preferences; students may perceive this behavioural pattern to be better suited for them to achieve the intended learning outcomes. The instructional design of the online pre-learning materials, particularly the mastery nature of the quizzes may have prompted students to adopt this approach. In future designs of the online component of a partially flipped learning model, adjustments may be made by limiting the number of attempts for the pre-learning quizzes which may reduce the tendency for students to guess whilst better capturing students' behavioural patterns.

5.4.4 The effect of students' behavioural patterns with the online pre-learning materials on their academic performance

The research reported in this chapter also adapted the approach suggested by Brennan et al. (2019) to cluster students' behavioural engagement into patterns based on measuring the frequency of access for each of the online pre-learning materials. While the identified behavioural patterns are highly context specific, they contribute to the field as the identified clusters of behavioural engagement are based on students' combined interaction with both the videos and quizzes, rather than on students' separate interaction with each of the pre-learning materials. The identified clusters of behavioural engagement are well differentiated and propose the presence of six distinct behavioural patterns. One of these behavioural patterns, where students' only access the video (BP_5), was not exhibited. As such, only five distinct behavioural patterns will be discussed in relation to their impact on academic performance.

When comparing students identified weekly behavioural pattern with their weekly quiz score there is an association between the frequency of access of the videos and the performance in the related quiz. Intuitively, it was hypothesised that students who displayed a behavioural pattern that accessed both pre-learning materials would perform better in the weekly pre-learning quiz. This was evident in two of the behavioural patterns (BP_3 and BP_4), where students that accessed the videos equally or more frequently when compared to the quiz tended to perform better than the remaining behaviours in each week. Conversely, in a third behavioural pattern (BP_2) where students accessed the videos less frequently, lower scores were observed in the weekly quizzes. Although a causal link cannot be concluded, it is possible to suggest that the frequency of viewing the videos may improve students' weekly performance in the associated quizzes.

Some reasons that might influence changes in students' weekly behavioural pattern may be related to their proficiency level (i.e., prior knowledge) of the presented weekly chemistry concepts but may also be attributed to the instructional design of the online component of the model. The videos are designed with the intent to be viewed prior to the quizzes as they are closely aligned with the concepts assessed in the quizzes and provide the foundational knowledge needed for the in-class sessions. Students' prior knowledge and familiarity with the weekly chemistry concepts may, however, have influenced the frequency of access for the videos and thus may affect which behavioural pattern they will adopt. The level of difficulty of the concepts addressed in the pre-learning materials may either inhibit or encourage certain behaviours (Dooley & Makasis, 2020).

While it was not feasible to examine individual variations and the order in which each student accessed the pre-learning materials in each attempt, by clustering students' behaviours, some inferences can be drawn from the cohort data. For instance, a student who has less background knowledge may opt to access the videos more frequently compared to those with sufficient background knowledge. However, various complex factors may have influenced students to display a particular behavioural pattern. Further insight may be gained by exploring individual variations across the different behavioural patterns and interview responses may be gathered to elicit the reasons behind the displayed behavioural approach. Another factor that may influence students' displayed behaviour is the learning process and strategies (i.e., approach to learning) they adopted while interacting with the pre-learning materials. This will be explored further in Chapter 6 to examine the relationship between students' self-identified approach to learning and displayed behavioural pattern.

Further analysis compared students' overall behavioural pattern with their pre-learning quiz score, end of semester examination and overall theory course performance. The cohort data for both groups identified the dominant behavioural pattern to be BP_2 which revealed that students accessed the quizzes more frequently than the videos. Students that displayed BP_2 overall for Group B_1 performed better in semester 1 in their pre-learning quiz score when compared to the remaining behavioural patterns. Significant differences were noted only between BP_2 and BP_4 where those students accessed the videos more frequently than the quizzes. Although not significant, a shift was noted in semester 2 with students accessing both pre-learning materials equally (BP_3) performed better than those in the remaining behavioural patterns. For Group B_2, students who accessed only the quiz (BP_1) in semester 1 and those that displayed BP_2 in semester 2 performed better than those in the remaining behavioural patterns. While it is not possible to establish a clear trend from these data, it is worth noting that when comparing changes across semesters, there is an overall trend towards increasing access of the videos in the second semester. A potential factor that may have contributed to these observed results is related to the course content. As noted above, concepts in semester 2 are traditionally perceived to be harder and tend to be more focused on organic chemistry. As such, students may have opted to utilise the videos more often in the second semester to aid in comprehending the weekly concepts and achieve better scores in the quizzes. The pre-learning materials were purposefully designed to provide foundational knowledge needed for the in-class component; students' prior knowledge may have influenced their level of access to the video. The mastery nature of the quizzes and the incentive mark associated with the quizzes may have simply prompted students to adopt behaviours that reflect more frequent access to the quizzes, such as BP_1 and BP_2. The format of the quiz questions (single best answer, short answer questions or drag and drop) which were designed to target lower cognitive processing skills (Bloom's Taxonomy) may have also encouraged students to display BP_1 and BP_2 compared to short answer questions or extended response questions that might require students to display a different set of behaviour. Subsequent sections will identify reasons behind students displayed interaction with each of the pre-learning materials.

Few significant relationships were observed when comparing students overall behavioural pattern with their academic performance in the end of semester examination and overall theory course performance. One potential reason for this may be that it is difficult to isolate the direct effect and the extent to which varying behavioural pattern with the pre-learning materials may have contributed to students' academic performance. This is less likely to be the case when comparing the impact of the videos on the performance of the quizzes as they are purposefully designed to be linked directly with the matching video.

On a course level, the most pronounced differences were observed in the mainstream courses for both groups, with BP_2 being the dominant displayed behavioural pattern. Students for Group B_1 that displayed BP_2 in semester 1 performed significantly better in the pre-learning quiz when compared to those that displayed BP_4. Whereas students that displayed BP_3 in semester 2 performed significantly better when compared to those that displayed BP_4. Students that displayed BP_2 also performed significantly better when compared to those in BP_4. Students for Group B_2 that displayed BP_2 in both semesters performed significantly better than students displaying the remaining behaviour patterns. This reinforces the point made above regarding how the level of difficulty of the concepts delivered in each semester may encourage or inhibit certain behaviours. No clear trend in the dominant behaviour pattern was observed for the advanced and the SSP courses; little or no change was observed in the academic performance of the pre-learning quizzes, end of semester examination and overall theory course performance. The observed trends were proposed to be related to students' proficiency level of chemistry, with students in the mainstream courses tending to have a weaker background in chemistry than those in the advanced and SSP courses. In this case, mainstream students may display a range of behavioural patterns to accommodate for their weaker prior knowledge of a particular concept compared to the advanced or SSP students who may simply opt to do the quizzes without needing to access the learning videos.

5.4.5 Students' identified learning behaviour and engagement index in their academic performance

Comparison of students displayed behavioural pattern (BP_1 to BP_6) with respect to the students' engagement level (low, moderate, and high) demonstrated no significant differences in their academic performance as measured by the end of semester examination and overall theory course performance, however, several trends were observed in their pre-learning quiz performance.

It was hypothesised that low engaged students would predominately display BP_1 or BP_2 when they would access the quizzes more frequently than the videos. Students who displayed BP_6 were also considered to have lower level of engagement. It was also hypothesised that highly and moderately engaged students would predominately display BP_3 or BP_4 as these patterns are indicative of higher levels of engagement with students equally or more frequently accessing the videos in comparison to the quizzes. Instead, the cohort data for Group B_1 and Group B_2 revealed that students who adopted BP_2 in the moderately and highly engaged group performed significantly better in pre-learning quiz performance when compared to the remaining behavioural patterns. The most pronounced differences in pre-learning quiz performance were observed in the low engaged students across both semesters. The dominant behavioural pattern for Group B_1 in semester 1was BP_2 whereas for Group B_2 , it was BP_1. Students in these behavioural clusters performed significantly better in the pre-learning quiz than those in the remaining behavioural patterns. The dominant behavioural pattern across both groups in semester 2 was BP_2 with low engaged students performing significantly better in the pre-learning quiz.

The results presented in this thesis are somewhat preliminary and highly context specific. Several factors may have contributed to the apparent lack of association between students displayed behavioural pattern, their level of engagement and their academic performance in the end of semester examination and overall theory course performance. As noted above, it is difficult to isolate the extent to which variation in behavioural patterns contributed to students' academic performance. Since the behavioural patterns were developed based on students' interaction with each of the online pre-learning materials, it was possible to observe the direct impact of adopting a specific behavioural pattern on students' pre-learning quiz performance. Although the students' engagement level did not align with the predicted behavioural approach, the results in general revealed that students tend to display BP_2, which reflects their preference for accessing the quiz more frequently than the videos.

Brennan et al. (2019) proposed that the frequency of access, i.e., students displayed behavioural pattern, does not reflect the level of engagement with the content in the pre-learning materials. Whilst no significant differences in academic performance were detected between students displaying behavioural patterns and engagement levels, previous findings discussed in Chapter 4 revealed that higher levels of engagement with the pre-learning material led to significant improvements in academic performance and a reduction in failure rates. The findings discussed here, however, highlight the direct link between the displayed behavioural pattern and the academic performance in the overall learning quiz. As previously outlined, the displayed behavioural pattern does not necessarily reflect the level of engagement students may adopt. Instead, the mastery design of the pre-learning quizzes may have encouraged all students, despite differences in their engagement levels, to access the quizzes more frequently. While no further inferences can be drawn about possible reasons behind the dominant behavioural pattern being BP_2, Jovanović et al. (2017) proposed that students' approach to learning can influence their displayed behavioural pattern, which will be further explored in Chapter 6. Subsequent sections will also discuss students' perception towards their learning and identify the reasons behind students' interaction or lack of with each of the videos and quizzes.

5.4.6 Students' perceptions towards the pre-learning materials of a partially flipped learning model

This chapter extended current research on students' perception of learning in a partially flipped learning model by focusing on the pre-learning materials (Long et al., 2016; O'Flaherty & Philips, 2015). Several studies have revealed that students tend to have a more positive perception towards learning in a flipped learning environment when compared to a traditional learning (O'Flaherty & Philips, 2015; Roach, 2014). Some have suggested that students value this instructional approach due to the flexibility it offers in independently accessing the online pre-learning materials at a pace that suits their learning needs (Long et al., 2016; Xiu et al., 2019). Fewer studies, however, have focused on the reasons behind students' interaction with the various online pre-learning materials (Christiansen, 2014; Shattuck, 2016).

The quantitative students' responses presented in this thesis identified several factors behind students accessing the videos and quizzes. The two main reasons identified by students for accessing the videos were (1) to improve their performance in the associated pre-learning quizzes and (2) valuable learning resource to develop foundational knowledge of chemistry. Fewer students did not access the videos as they perceived them not to be helpful or needed to successfully complete the quizzes. The main reasons outlined by students for accessing the quizzes were (1) the incentive mark, (2) a learning tool to assess their level of understanding from the pre-learning videos, and (3) a revision tool. Students' open-ended responses expanded on some of the above-mentioned reasons and may in part explain some of the behavioural patterns observed across both groups.

Generally, students appreciated the cohesive link between the pre-learning materials and the seamless transition between the content presented in the online component to those presented during the in-class sessions. They perceived the pre-learning materials to be an effective tool in offering individualised and personalised learning experiences. In addition, they appreciated the flexibility of accessing the pre-learning materials at a pace that suits their individual learning needs which also aligns with several studies that also suggest the pre-learning materials promote students' autonomy (He et al., 2016; Long et al., 2016; Poniker & Patel, 2018; Xiu et al., 2019).

One feature that students appreciated about the videos was the visual support that supplemented the spoken explanation. This design feature also adheres to the *multimedia principle* (Mayer, 2005) as it allowed students to simultaneously reinforce their conceptual understanding and develop dynamic mental models with the presented concepts (Velázquez-Marcano, Williamson, Ashkenazi, Tasker & Williamson, 2004). Students also valued the auto-generated feedback mechanism embedded in the quizzes, which helped students address potential gaps and address misconceptions in their knowledge. These results, in conjunction with those of Long et al. (2016) and Ponikwer and Patel (2018), reinforce the perceived value of the pre-learning materials as a learning tool that provides foundational knowledge prior to attending the in-class sessions whilst offering individualised support to guide students' learning process.

The remaining open-ended comments focused on improvements that may be made to each of the pre-learning materials to further enhance students' learning experiences. Some students proposed that the videos should be more interactive (Lebedev, Lindstrøm, & Sharma, 2020) which could be achieved by embedding the quiz questions at various segments. This has practical implications for future designs of the model, as it transforms the videos into an active learning tool where students are not only receiving the knowledge by watching the videos but also by simultaneously applying the knowledge and measuring their level of understanding. Long et al. (2019) investigated the impact of interactive pre-learning videos and noted they were generally well received by students and led to significant improvements when compared to a control group. These findings also align with those of O'Flaherty and Philips (2015) who noted that students are more likely to engage with pre-learning materials if they include interactive features, provide formative feedback mechanisms, and are coherently linked to the in-class component. This proposed instructional change may also lead to increased participation rates with the videos leading to a shift away the dominant behavioural pattern from being BP_2 to one that encourages students to access both pre-learning materials. Other suggestions focused on the quizzes. Some students suggested that the learning quizzes may include hints and prompts to help them solve harder applications whereas others requested additional questions to further extend their knowledge beyond the weekly materials presented. These suggestions reflect the diversity of students' learning needs with some requiring scaffolding to support their learning while others requested questions that further extends their conceptual knowledge. These suggestions can also have practical implications as the design of the quizzes could influence students displayed behavioural pattern. For instance, if the level of difficulty of the pre-learning quizzes was adjusted to suit the learning needs of various students, it may be possible that some students would need to access the videos to gain the foundational knowledge needed to answer some of the questions and, as such, shift away from the dominant behavioural pattern being BP_2.

Chapter 6: Students' approaches to learning in the online component of a partially flipped learning model

6.1 Introduction

This chapter explores the relationship between students' self-identified approach to learning with the online component of the partially flipped learning model and their academic performance. Furthermore, it compares the academic performance of this approach to learning with respect to their engagement level (as categorised in Chapter 4) and their behavioural pattern (as categorised in Chapter 5).

Marton and Säljö's (1976) seminal work identified the fundamental principles related to students' approaches to learning and classified them into two main levels of processing: surface and deep. Others have proposed a third level of processing: the achieving or strategic approach. This level suggests that students do not necessarily have to lean towards a specific approach but instead can alternate between surface and deep learning approaches (Biggs, 1987; Kember, & Leung, 1998; Ramsden, 1979). Further research conducted by Biggs (1987) conceptualised approaches to learning into two main sub-components: motive and strategy. Students adopting a surface approach to learning are extrinsically motivated in the learning process. They adopt strategies such as rote learning and use lower-level cognitive skills as they intend to put minimal time and effort into completing an assigned task (Biggs, 1987). Students adopting a deep approach to learning are intrinsically motivated by the learning process. They adopt strategies to seek meaning and increase their level of understanding, by using higher-level cognitive skills to relate newly acquired knowledge to previous understanding (Biggs, 1987).

The R-SPQ-2F questionnaire is a widely used tool that measures students' approaches to learning in their current learning environment. It evaluates the learning context instead of classifying students as either surface learners or deep learners (Biggs, 1987; Biggs et al., 2001). It has been proposed that a flipped learning environment has the potential to influence students' approaches to learning and promote deep engagement with the learning materials (Hava, 2021; Sigurðardóttir & Heijstra, 2020). Jeong et al. (2019) found that by the end of a course, students had a general inclination towards adopting a deep approach to learning in a flipped learning environment based on comparing their R-SPQ-2F questionnaire responses pre-and post-course completion. One of the leading factors that contribute to observed shifts in students' approaches is course design. Another study reported that students adopt a mixed approach to learning in the flipped classroom (Sigurðardóttir & Heijstra, 2020). An underlying assumption made in that study is that students' preparedness and interaction with the pre-learning materials can facilitate deep learning to occur during the interactive learning component of the in-class sessions. However, limited research has focused on examining the approach students adopt whilst completing the online pre-learning materials as, irrespective of the approach students adopted, they are expected to deeply engage with the learning materials presented in the in-class sessions. Since the pre-learning materials are designed to provide students with foundational knowledge prior to the in-class session, they may be limited in their scope and may be perceived to be passive in nature in comparison to the learning activities embedded in the in-class sessions. Moreover, it is essential to consider how students' individual preferences and other related personal factors can influence their learning approach with the online pre-learning materials.

The research reported in this chapter seeks to further explore students' self-identified approach to learning with the pre-learning material, as measured by the R-SPQ-2F questionnaire. Furthermore, observational case studies provided valuable qualitative insight regarding the students' displayed approach towards learning in the online component of the partially flipped learning model. The relationship between students self-identified approach to learning and its impact on their academic performance whilst considering their engagement level and displayed behavioural pattern have also been analysed.

The following research questions are addressed in this chapter:

1. How do students approach learning in the online component of the flipped learning model and how does it affect their academic performance?
2. How does students' self-identified approach to learning relate to their behavioural engagement and their behavioural pattern in the online component?

6.2 Methodology

6.2.1 Participants

The participants of this study consisted of two groups of undergraduate chemistry students enrolled in junior and intermediate courses during 2017. Group A were undergraduate students in first semester junior courses. For Group B_2, analyses were only carried out for undergraduate chemistry students in first semester intermediate chemistry courses. See Sections 3.8 and 3.9 for full description for each of the chemistry courses.

6.2.2 Procedures

6.2.2.1 Survey

Biggs et al.'s (2001) R-SPQ-2F questionnaire was administrated online at the beginning of the semester to identify students' metacognitive approaches to learning (see Appendix D). The R-SPQ-2F questionnaire includes twenty items and is divided into two main scales: deep approach (DA) and surface approach (SA). These two main scales are comprised of four sub-scales. The DA scale includes deep motive (DM) and deep strategy (DS); the SA scale includes the surface motive (SM) and surface strategy (SS). Each sub-scale consists of five items with a 5-point Likert-type scale ranging from Strongly Disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly Agree = 5. The questionnaire items for the related sub-scales and main scales are outlined in Table 6.1.

Section 6.2.2.2 explains in detail how students' self-identified approach to learning was determined from the questionnaire.

Table 6.1. The R-SPQ-2F questionnaire items related to the subscales and main scales.

Main scale	Sub-scale	Questionnaire items
Deep scale	Deep Motive	1,5,9,13, and 17
	Deep Strategy	2,6,10,14, and 18
Surface scale	Surface motive	3,7,11,15, and 19
	Surface strategy	4,8,12,16, and 20

6.2.2.2 Approach to learning with the online pre-learning materials

Students' self-identified approach to learning preference was determined from their responses to the R-SPQ-2F questionnaire. Each student received two scores: one for the DA scale and one for the SA scale. To obtain a mean score for the DA scale, responses for the DM and DS were used. To obtain a mean score for the SA scale responses for the SM and SS were used. The scores for each of the four sub-scales (DM, DS, SM, and SS) were obtained by combining the related questionnaire items (see Table 6.1).

This work adapted the method used by Leiva-Bronda et al. (2020) to explore students approaches to learning using the R-SPQ-2F questionnaire. In their study, the overall mean value for the DA and SA scales were used as boundaries to plot the distribution of scores for each student. The work described here builds on this method by categorising the distribution of the approaches to learning into one of four quadrants based on students' scores in the DA and SA scale. The distribution of the approaches to learning into one of the four quadrants is based on students' scores in the DA and SA scale. To determine the boundaries between the quadrants, the mean score for the DA scale and SA scale was calculated for each group. As an example, in Figure 6.1, if the overall mean value for the DA scale was calculated to be X (i.e., 2.5 as seen in the example) and the overall mean value for the SA scale was calculated to be Y (i.e., 2.5 as seen in the example), these mean values would be the boundaries between the quadrants. Depending on the student's DA score relative to the mean value of the group, they would be identified as either having a high deep approach (HDA) score or a low deep approach (LDA) score. Similarly, depending on the student's SA score relative to the mean value of the group, they would be identified as either having a high surface approach (HSA) score or a low surface approach (LSA) score.

The first quadrant Q_1 represents students who achieved a HDA and LSA score. The second quadrant Q_2 represents students who achieved a HDA and HSA score. The third quadrant Q_3 represents students who achieved a LDA and LSA score. The fourth quadrant Q_4 represents students who achieved a LDA and HSA score.

Students in Q_1 are classified as having an overall deep approach towards their learning since they have a HDA score and a LSA score. Students in Q_4 are classified as having an overall surface approach towards their learning since they have an HSA and a LDA score. Students in Q_2 and Q_3 are classified as strategic in their learning since they have been identified as having either HDA and HSA or a LDA and LSA.

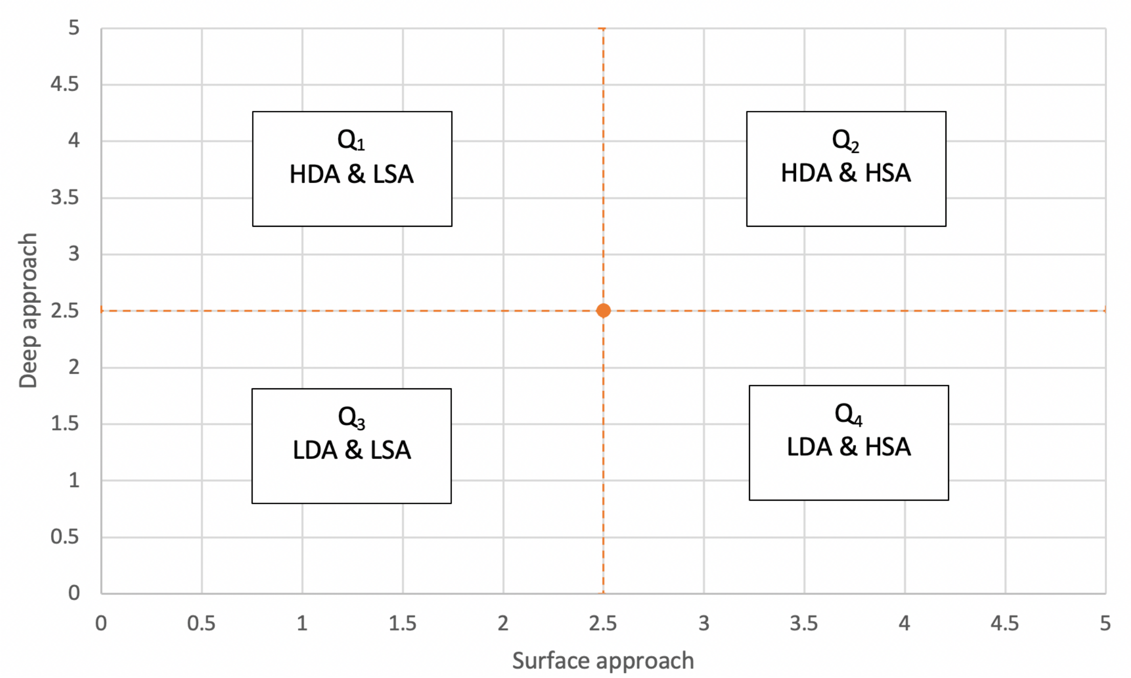

Figure 6.1. Example of deep approach (DA) and surface approach (SA) distribution of scores based on R-SPQ-2F questionnaire.

6.2.2.3 Observational session

Observational sessions were conducted with Group A (n = 6) and Group B_2 (n = 3). During these sessions, students were instructed to complete one of the weekly pre-learning materials under the researcher's supervision. Students' online behavioural engagement with each of the pre-learning materials was monitored by recording the number of times each of the pre-learning videos and pre-learning quizzes were accessed. Furthermore, the sequence of events in students' interaction with the pre-learning materials as they unfolded during the observational sessions were noted and analysed as case studies. The approach to learning adopted by the students' during their interaction with the pre-learning materials was categorised based on Entwistle's (2000) characterisation features of surface, strategic, and deep approach (Table 6.2). The intention of these case studies is to provide an in-depth exploration of how students' approach the weekly pre-learning material and whether their observed approach correlates with their self-identified approach to learning that was derived from the R-SPQ-2F questionnaire.

Table 6.2. Defining features of approaches to learning (extracted from Entwistle, 2000).

Surface approach	Strategic approach	Deep approach
Passively reproduction	*Reflective organising*	*Actively transforming*
Intention – merely to cope with course requirements by:	*Intention* - to achieve the highest possible grades by:	*Intention* - to understand ideas for yourself by:
Treating the course as unrelated bits of knowledge	Putting consistent effort into studying	Relating ideas to previous knowledge and experience
Memorising facts and carrying out procedures routinely	Managing time and effort effectively	Looking for patterns and underlying principles
Finding difficulty in making sense of new ideas presented	Finding the right conditions and materials for studying	Checking evidence and relating it to conclusions
Seeing little value or meaning in either courses or tasks set	Monitoring the effectiveness of ways of studying	Examining logic and argument cautiously and critically
Studying without reflecting on either purpose or strategy	Being alert to assessment requirements and criteria	Being aware of understanding developing while learning
Feeling undue pressure and worry about work	Gearing work to the perceived preferences of lecturers	Becoming actively interested in the course content

6.2.2.4 Interviews

Follow-up interviews were conducted by the researcher with the students who consented to the observational sessions (n = 6) Group B_2 (n = 3). A semi-structured interview was conducted to elicit the reasons behind students' adopted approach during the supervised observational session and how these could influence their academic performance (See Appendix E). The semi-structured interview questions build on those widely used to explore students' approaches towards learning but with a narrower focus on students' interaction with the online pre-learning materials (Bliuc, et al., 2010; Hamm & Robertson, 2010). For instance, students were asked to verify their observed behaviour and expand on whether their described approach is typical of their normal approach to learning. Depending on students' responses, follow-up interview questions focused on factors that may have encouraged or inhibited them to adopt a particular approach to learning.

6.3 Results

6.3.1 Participation rate for each junior and intermediate chemistry course

The overall participation rate across the three junior chemistry courses for Group A during semester 1 was 23% (*n* = 386). For Group B_2, the overall response rate across the three intermediate chemistry courses for semester 1 was 18% (*n* = 48). The response rate for each of the individual chemistry courses for Group A and Group B_2 are shown in Table 6.3.

Table 6.3. Response rate for each junior and intermediate chemistry course.

	Group A			Group B_2	
	Participants	Participation rate		Participants	Participation rate
	n	%		*n*	%
CHEM1001	116	20	CHEM2401	32	18
CHEM1101	214	23	CHEM2911	13	21
CHEM1901	56	28	CHEM2915	3	14
Total	386	23	Total	48	18

6.3.2 Approaches to learning preference in Group A

Students' self-identified approach to learning was initially analysed at a cohort level by combining responses to the R-SPQ-2F questionnaire from all three junior chemistry courses (see Figure 6.2).

A one-way ANOVA showed a significant difference between the mean scores across the four subscales of the R-SPQ-2F questionnaire [$F_{3,\,1540}$ = 621.33, $p < 0.001$, $d = 0.086$].

A one-way ANOVA showed a significant difference between the mean scores across the two main scales for the R-SPQ-2F questionnaire [$F_{1,\,770}$ = 1012.07, $p < 0.001$, $d = 0.086$]. A post-hoc Tukey's *t*-test indicated that the mean score for the DA scale was significantly higher than that of the SA scale.

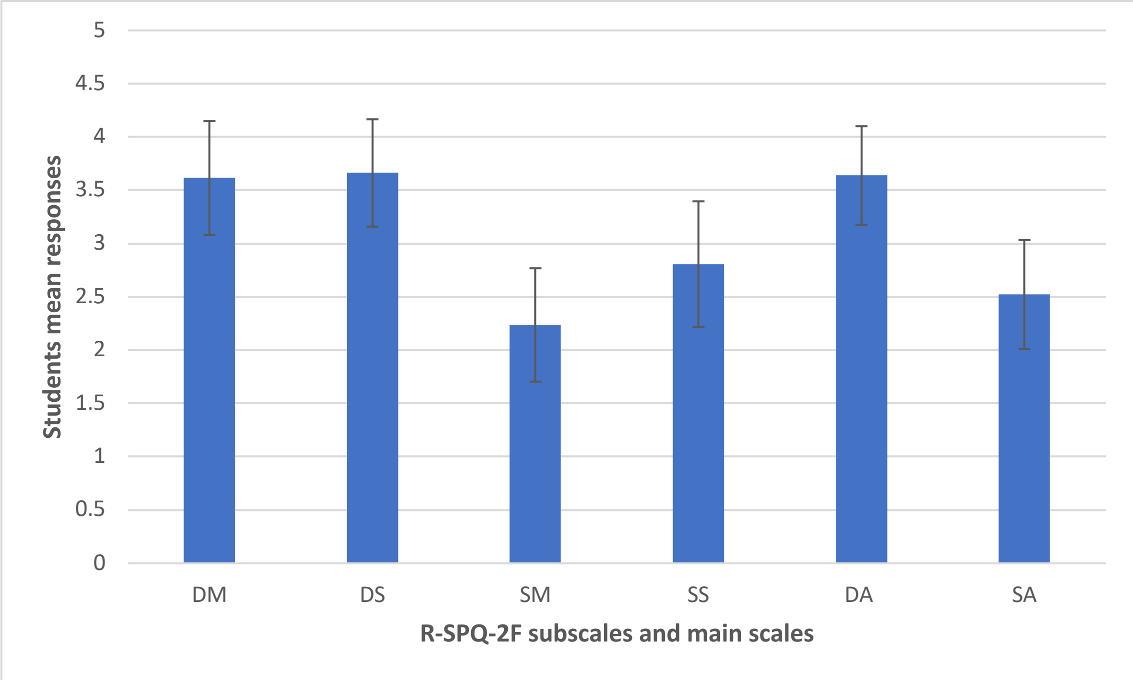

Figure 6.2. Distribution of R-SPQ-2F subscales and main scales values across Group A (n = 386).

Note. DM = deep motive, DS = deep strategy, SM = surface motive, SS = surface strategy, DA = deep approach and SA = surface approach. Error bars represent standard errors.

Students' self-identified approach to learning was analysed at a course level (see Figure 6.3). A one-way ANOVA showed no significant differences between the mean scores for the DM, DS and SM sub-scale of the R-SPQ-2F questionnaire between the three junior courses. However, there was a significant difference between the mean score for the SS sub-scale [$F_{2, 383} = 4.05$, $p < 0.05$, $d = 0.086$]. A post-hoc Tukey's *t*-test indicated that the mean score for CHEM1001 was significantly higher than CHEM1101 (see Table 6.4).

A one-way ANOVA showed no significant difference between the mean scores for the main DA scale between the courses. However, there was a significant difference between the mean scores for the main SA scale between the courses [$F_{2, 383} = 3.62$, $p < 0.05$, $d = 0.086$]. A post-hoc Tukey's *t*-test indicated that the mean score for CHEM1001 was significantly higher than CHEM1101 (see Table 6.4).

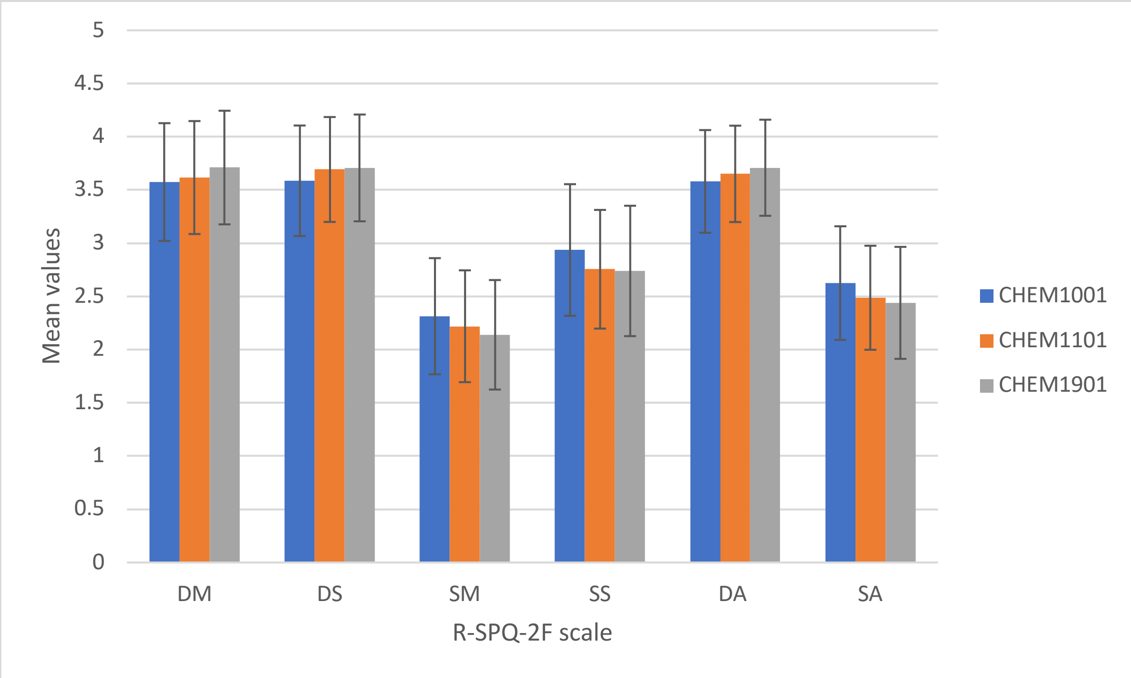

Figure 6.3. Distribution of R-SPQ-2F subscale and main scales values across junior chemistry courses in Group A (n = 386).

Note. DM = deep motive, DS = deep strategy, SM = surface motive, SS = surface strategy, DA = deep approach and SA = surface approach. Error bars represent standard errors.

Table 6.4. R-SPQ2F scores for junior chemistry courses.

		Sub-scale		Main scale	
		Surface strategy		Surface approach	
	n	M	SD	M	SD
CHEM1001	116	2.94	0.52	2.63	0.54
CHEM1101	214	2.76	0.56	2.49	0.49
CHEM1901	56	2.74	0.59	2.44	0.53

Note. M = mean, SD = standard deviation.

6.3.2.1 Distribution of approaches to learning preference

The distribution of approaches to learning preference was analysed at a cohort level (see Figure 6.4). The scores are categorised in Q_1-Q_4 and depend on students' relative DA and SA scores from the mean values. The mean value for the DA was 3.64 and for the SA scale was 2.52. The mean values plus the standard deviation for the DA was 4.10 and for the SA scale was 3.03. The mean value minus the standard deviation for the DA was 3.18 and for the SA scale was 2.01 scale.

The results indicated that most of the intermediate chemistry students self-identified their learning approach to be deep as indicated in Q_1 (n = 120) or to be surface as shown in Q_4 (n = 116). The remaining students were identified to be strategic in their learning as indicated in Q_2 (n = 72) and Q_3 (n = 78).

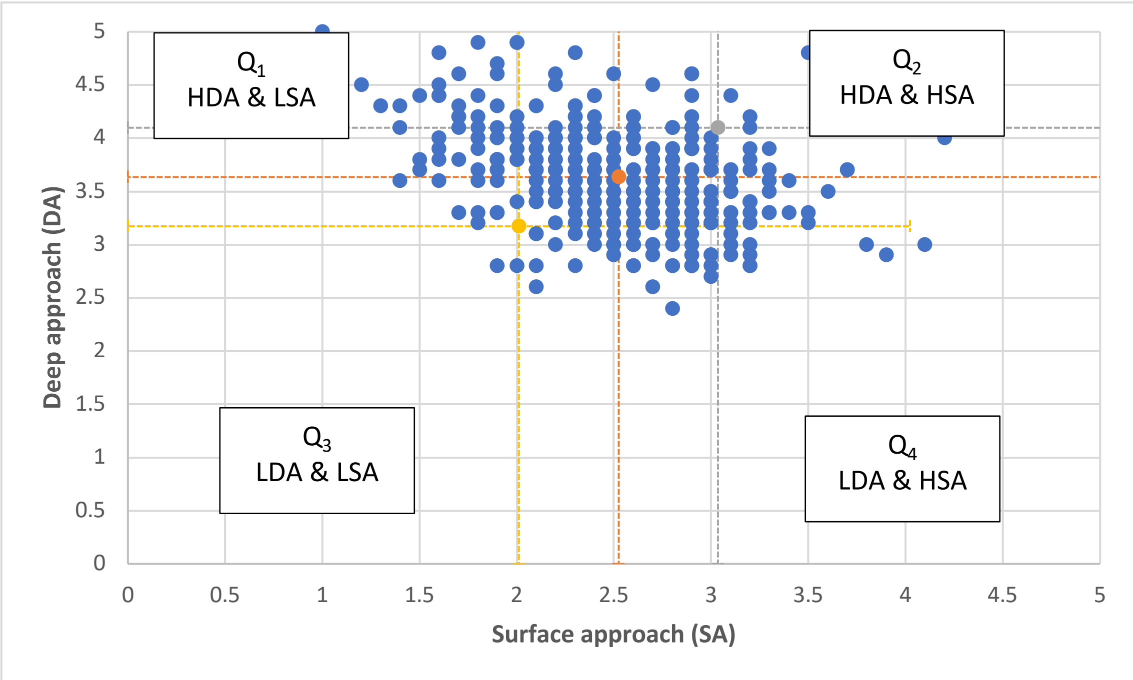

Figure 6.4. Distribution of student scores based on the R-SPQ-2F questionnaire (n = 387) for Group A.

Note. HDA = high deep approach, LDA= low deep approach, HSA = high surface approach, LSA = low surface approach. The orange line depicts the mean value for the DA (3.64) and SA (2.52) scale. The grey line represents the mean values plus the standard deviation for the DA (4.10) and SA (3.03) scale, the yellow line represents the mean value minus the standard deviation for the DA (3.18) and SA (2.01) scale. Each blue dot represents the score of one student and has two corresponding values one from the DA scale and one from the SA scale.

When examining the distribution of students' approaches to learning on a course level, several trends were observed (see Table 6.5). For CHEM1001, most of the students self-identified their learning approach to be surface as reflected in Q_4 (n = 42). For CHEM1101 and CHEM1901, most of the students self-identified their learning approach to be deep as shown in Q_1 (n = 72) and Q_1 (n = 20) respectively.

Table 6.5. Distribution of students' R-SPQ-2F self-identified approaches to learning on a cohort level and course level in Group A.

	Self-identified approach based on R-SPQ-2F questionnaire				
		Deep approach	Strategic approach		Surface approach
	n	Q_1	Q_2	Q_3	Q_4
CHEM1001	116	28	24	22	42
CHEM1101	214	72	39	46	57
CHEM1901	56	20	9	10	17
Total	386	120	72	78	116

Note. Q_1 = HDA & LSA, Q_2 = HDA & HSA, Q_3 = LDA & LSA and Q_4 = LDA & HSA. HDA = high deep approach, LDA = low deep approach, HSA = high surface approach, LSA = low surface approach.

6.3.2.2 Approaches to learning and academic performance for Group A

Given that the overall sample size for each of the three junior chemistry courses is small and few students are present in each of the quadrants, the analysis related to the impact of varying approaches to learning on academic performance will only be explored at the full cohort level (see Table 6.6). To analyse students' academic performance, the pre-learning quiz score, end of semester examination and overall theory course performance were used.

6.3.2.2.1 Academic performance of varying approaches to learning for Group A

The cohort data revealed that students in Q_1 performed better in the end of semester examination and overall theory course performance (see Table 6.6). Students in Q_2 performed better in the pre-learning quizzes. A one-way ANOVA showed significant differences in the academic performance for students in the pre-learning quizzes across the three approaches to learning as identified by the four quadrants (Q_1- Q_4).

Table 6.6. Academic performance of Group A across the varying approaches to learning quadrants.

	Pre-learning quiz			End of semester examination		Overall theory course performance	
	n	M	SD	M	SD	M	SD
Q_1	120	9.40	1.62	27.31	11.48	36.34	9.61
Q_2	72	9.69	0.99	27.79	9.67	38.72	14.03
Q_3	78	9.17	2.09	25.10	9.83	55.15	10.72
Q_4	116	8.27	1.18	26.10	10.60	41.15	19.88

Note. M = mean, SD = standard deviation, Q_1 = HDA & LSA, Q_2 = HDA & HSA, Q_3 = LDA & LSA and Q_4 = LDA & HSA. HDA = high deep approach, LDA = low deep approach, HSA = high surface approach, LSA = low surface approach.

6.3.2.3 Observational case studies for Group A

6.3.2.3.1 Case study 1

Based on the R-SPQ-2F questionnaire, the participant self-identified as HDA and LSA. From the observational session, the participant's behavioural pattern was BP_3. The participant accessed both pre-learning materials twice.

During the observation, the participant displayed characteristics of deep learning when accessing the pre-learning video. Initially, they watched it making some reference notes. In their second view, they focussed on certain sections related to the questions they answered incorrectly from the quiz. Focusing on certain sections in their second video view could be indicative of a deep approach as they may have been seeking clarification of a specific concept, or a surface approach as they try to elicit the answer from the video. The participant's comment revealed that they initially access the video to "*give me an idea on what we will cover during class and good to know what will be covered in the quiz*". It was noted by the participant that the videos "*sometimes explain things in a simple way, and I find that they link well to the quiz".*

A deep approach was also reflected in their quiz attempts. Initially, the participant attempted the quiz and spent time reading the feedback provided for each question irrespective of their selected answers. In the second quiz attempt, the participant made constant reference to the notes made from the videos. Although the participant attempted the pre-learning quiz in a thorough manner, their comments were not all positive: "*quiz are straight forward sometimes* *the questions get repetitive, maybe because they are focusing on certain concept maybe in future they can include more of a variety and make them a bit more difficult".* The participant indicated that they read the feedback provided *"because I might learn something in an easier way than I originally thought so yeah it is there so why not".*

6.3.2.3.2 Case study 2

Based on the R-SPQ-2F questionnaire, the participant self-identified as HDA and LSA. From the observational session, the participant's behavioural pattern was BP_4. The participant watched the video twice and attempted the quiz once.

During the observation, the participant displayed characteristics of deep learning when accessing the pre-learning materials. After watching the video for the first time, the participant made some reference notes. They then re-watched the video before attempting the quiz. In their only quiz attempt, the participant read each question and solved it by making references to the video notes and reading the feedback provided after each question.

Interview responses supported the observed approach and the participant preferred to access the videos before attempting the quiz *"to get an idea about the content covered"*. This approach was perceived by the participant to be helpful in achieving a full score in the quizzes *"by watching the video I can make sure I understand the content really well before doing the quiz, they are also nicely linked"*.

6.3.2.3.3 Case study 3

Based on the R-SPQ-2F questionnaire, the participant was self-identified as LDA and HSA. From the observational session, the participant's behavioural pattern was BP_1. The participant did not access the videos and attempted the quiz eight times.

During the observation, the participant displayed characteristics of surface learning when accessing the quiz. During the first three quiz attempts, the participant would answer a few questions and restart the quiz. From the participant comments, it was revealed that they restarted the quiz depending *"on which question I get up to if I get the first few wrong, I start again because I do not want to waste time doing all the questions"*. During the next set of attempts, the participant continued answering all the questions but for questions answered incorrectly they hovered over the provided answers to see which option was correct. This observed behaviour is indicative of a surface approach as the participant was interested in the answer rather than the feedback itself which is also reflected in the comment made *"I use the cursor to have a look at what the answer was"*. In the final two attempts, the participant completed them in a slower pace and indicated that "*if I get a 9 it is not worth it to do it again to get a 10* ".

Moreover, the participant adopted a surface approach towards learning whilst only accessing the quiz as they stated that *"I prefer to learn by repeating the quiz and don't feel I need to access any of the other material"*.

6.3.2.3.4 Case study 4

Based on the R-SPQ-2F questionnaire, the participant was self-identified as LDA and HSA. From the observational session, the participant's behavioural pattern was BP_3. The participant accessed both pre-learning materials once.

During the observation, the participant displayed characteristics of deep learning when accessing the video. The participant paused at multiple intervals and wrote down key points. During their quiz attempt, the participant was working out the questions on a notebook, making referencing to the video notes taken before selecting an answer. Feedback for each of the quiz questions was noted down irrespective of the selected answer.

Interview responses revealed that the participant chose to approach their learning in this way as they perceived *"the concepts are addressed in both the video and quiz"*. It was essential for them to be efficient in their learning "*instead of guessing and checking I watch the video and take my time when doing the quiz*". The participant also noted that the feedback *"is very helpful, it gives you trick on how to solve certain questions which is useful later on when we have to the tutorial quizzes and other assessment"*.

6.3.2.3.5 Case study 5

Based on the R-SPQ-2F questionnaire, the participant self-identified as HDA and HSA. From the observational session, the participant's behavioural pattern was BP_2. The participant watched the video twice and attempted the quiz twelve times.

During the observation, the participant displayed characteristics of both surface and deep learning when accessing the quiz. During the first few attempts, the participant completed all ten questions irrespective of whether they got the correct or incorrect answer.

The participant explained that they like to become familiar with concepts addressed and depending on the weekly concepts "*sometimes I do parts of the quiz and other times I do the whole thing* ". The participant also indicated the reason behind the multiple attempts was that "*I try to get full marks after a few times and if I do, I don't watch the video*". This is indicative of a surface approach as the participant is being selective in the way they are engaging with the learning material and, instead of accessing both pre-learning material, they are selecting which approach they adopt based on their needs. The participant would access the videos as a learning tool only to extract the knowledge that is related to the questions previously answered incorrectly.

In the final two quiz attempts, the participant displayed a deep approach towards their learning. For each question, they would write down their solution on a paper and then select the appropriate answer from the available options provided. The main reason given for this was that *"at times I want to test myself and check that I know I can solve them in case we need them for other exams"*.

6.3.2.3.6 Case study 6

Based on the R-SPQ-2F questionnaire, the participant self-identified as HDA and HSA. From the observational session, the participant's behavioural pattern was BP_2. The participant watched the video once and attempted the quiz five times.

During the observation, the participant displayed characteristics of both surface and deep learning when accessing the quiz. During the first four attempts, the participant completed all ten questions irrespective of whether they got a correct or incorrect answer. The participant noted the questions they got incorrect in each of these attempts. The participant then watched the video and tried to elicit the responses of the questions they incorrectly answered in the earlier attempts. Several points were noted before their last attempt.

During the last quiz attempt, the participant completed each question by referring to the notes they gathered from the videos and previous mistakes they made in the earlier attempts.

Interview responses indicated that the participant combined strategies that are indicative of both deep and surface learning, *"the way I do them works for me I get to see what the questions are like and then look for what I am missing in video and start again"*. In one way, the participant was adopting a procedural approach to gather the answer while also looking for patterns between the concepts presented.

6.3.3 Approaches to learning preference in Group B_2

Students' self-identified approach to learning was initially analysed at a cohort level by combining responses to the R-SPQ-2F questionnaire from all three intermediate chemistry courses (see Figure 6.5). One-way ANOVA results showed a significant difference between mean scores across the four subscales of the R-SPQ-2F questionnaire [$F_{3,188} = 33.29$, $p < 0.001$, $d = 0.086$]. A one-way ANOVA showed a significant difference between mean scores across the two main scales for the R-SPQ-2F questionnaire [$F_{1,94} = 40.89$, $p < 0.001$, $d = 0.086$]. A post-hoc Tukey's *t*-test indicated that the mean score for the DA scale was significantly higher than that of the SA scale.

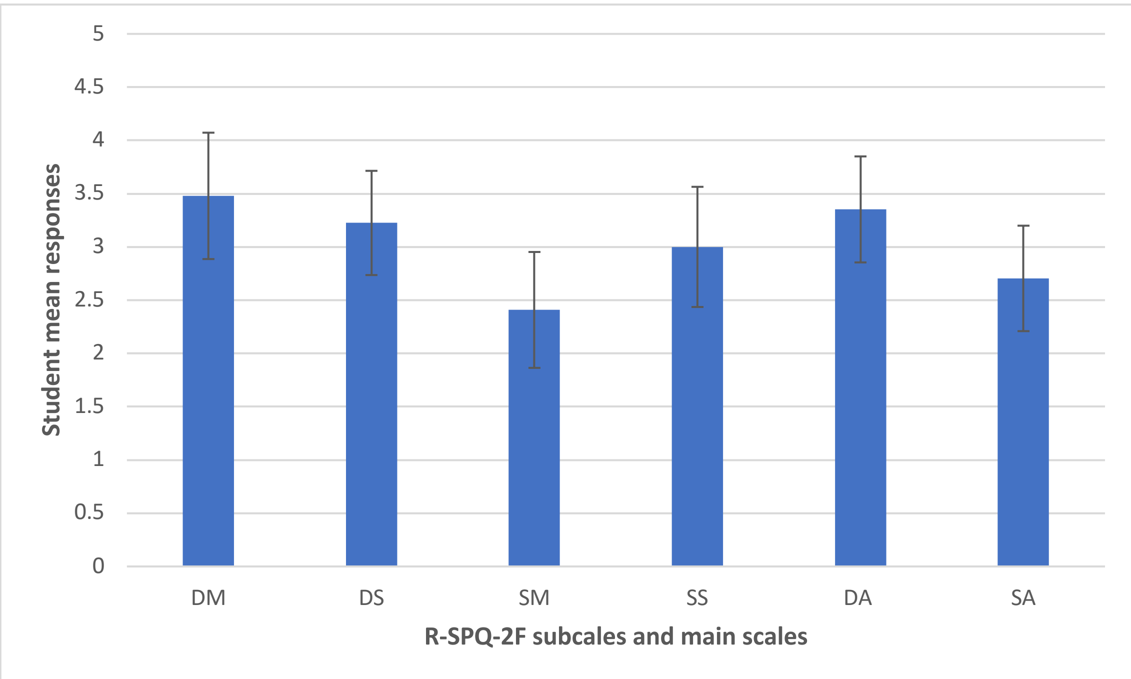

Figure 6.5. Distribution of R-SPQ-2F subscale and main scales values across intermediate chemistry courses in Group B_2 ($n = 48$).

Note. DM = deep motive, DS = deep strategy, SM = surface motive, SS = surface strategy, DA = deep approach and SA = surface approach. Error bars represent standard errors.

Students' self-identified approach to learning was analysed at a course level (see Figure 6.6). A one-way ANOVA showed no significant differences between mean scores for the DM, DS and SM sub-scales of the R-SPQ-2F questionnaire between the three intermediate courses. However, there was a significant difference between the mean score for the SS sub-scale [$F_{2,45}$ = 5.81, p < 0.001, d = 0.086]. A post-hoc Tukey's t-test indicated that the mean score for CHEM2401 was significantly higher than CHEM2915 (see Table 6.7).

A one-way ANOVA results showed no significant difference between mean scores for the main DA scale between the courses. However, there was a significant difference between mean scores for the main SA scale between the courses [$F_{2,45}$ = 5.81, p < 0.001, d = 0.086]. A post-hoc Tukey's t-test indicated that the mean score CHEM2401 was significantly higher than CHEM2911 (see Table 6.7).

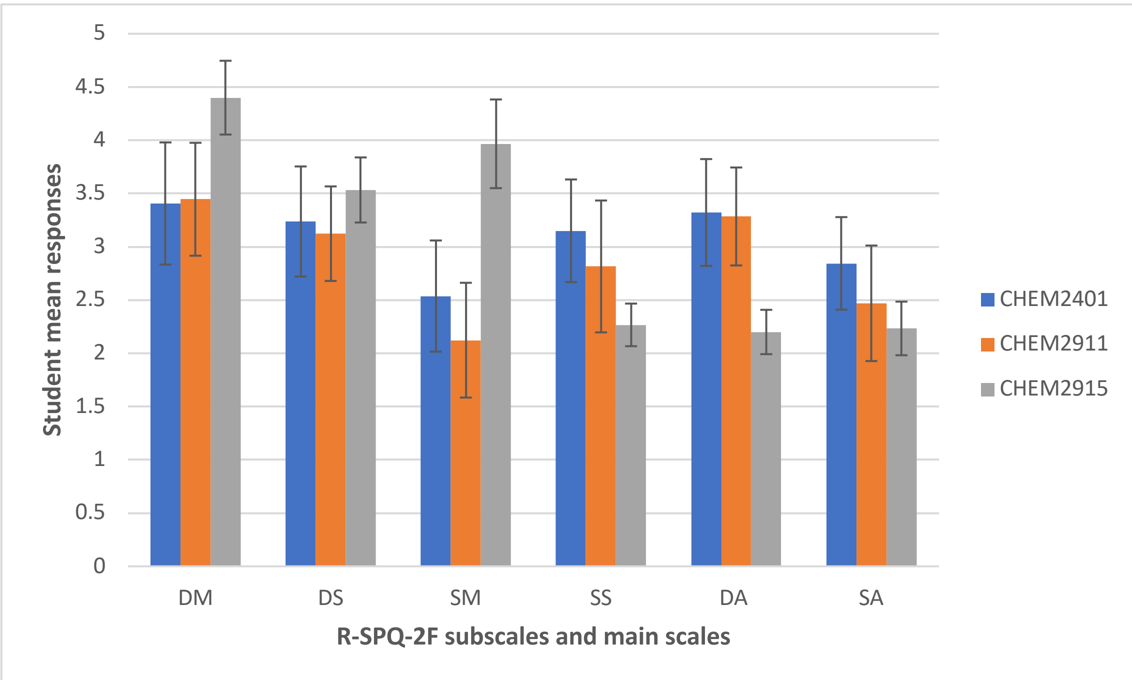

Figure 6.6. Distribution of R-SPQ-2F subscale and main scales values across each intermediate chemistry course, CHEM2401 (n = 32), CHEM2911 (n = 13) and CHEM2915 (n = 3) in Group B_2.

Note. DM = deep motive, DS = deep strategy, SM = surface motive, SS = surface strategy, DA = deep approach and SA = surface approach. Error bars represent standard errors.

Table 6.7. R-SPQ2F scores for intermediate chemistry courses in in Group B_2.

		Sub-scale		Main scale	
		Surface strategy		Surface approach	
	n	M	SD	M	SD
CHEM1001	32	3.15	0.48	2.84	0.43
CHEM1101	13	2.82	0.62	2.47	0.54
CHEM1901	56	2.2	0.2	2.23	0.25

Note. M = mean, SD = standard deviation.

6.3.3.1 Distribution of approaches to learning preference

The distribution of approaches to learning preference was analysed at a cohort level (see Figure 6.7). The scores are categorised in Q_1- Q_4 and depend on students' relative DA and SA scores from the mean values. The results indicated that the majority of the intermediate chemistry students self-identified their learning approach to be deep as indicated in Q_1 (n = 16) or to be surface as shown in Q_4 (n = 13). The remaining students were identified to be strategic in their learning as indicated in Q_2 (n = 11) and Q_3 (n = 8).

When examining the distribution of students' approaches to learning on a course level, a variety of trends were observed (see Table 6.8). For CHEM2401, most of the students self-identified their learning approach to be surface as reflected in Q_4 (n = 10). For CHEM2911 and CHEM2915, most of the students self-identified their learning approach to be deep as shown Q_1 (n = 5) and Q_1 (n = 3) respectively.

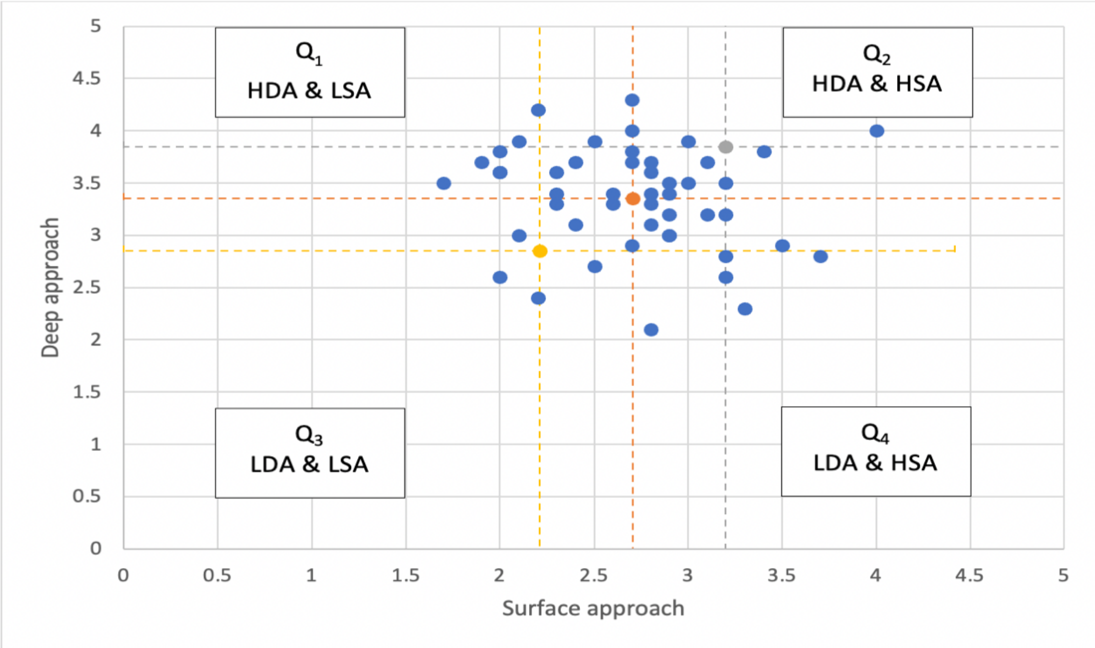

Figure 6.7. Deep approach (DA) and surface approach (SA) distribution of score based on the R-SPQ-2F questionnaire for each student in Group B_2 (n = 48).

Note. HDA = high deep approach, LDA= low deep approach, HSA = high surface approach, LSA = low surface approach. The orange line depicts the mean value for the DA (3.35) and SA (2.70) scale. The grey line represents the mean values plus the standard deviation for the DA (3.85) and SA (3.20) scale, the yellow line represents the mean value minus the standard deviation for the DA (2.85) and SA (2.21) scale. Each blue dot represents the score of one student and has two corresponding values one from the DA scale and one from the SA scale.

Table 6.8. Distribution of students' R-SPQ-2F self-identified approaches to learning on a cohort level and course level in Group B_2.

		Deep approach	Strategic approach		Surface approach
	n	Q_1	Q_2	Q_3	Q_4
CHEM2401	32	8	9	5	10
CHEM2911	13	5	2	3	3
CHEM2915	3	3	-	-	-
Total	48	16	11	8	13

Note. Q_1 = HDA & LSA, Q_2 = HDA & HSA, Q_3 = LDA & LSA and Q_4 = LDA & HSA, HDA = high deep approach, LDA = low deep approach, HSA = high surface approach, LSA = low surface approach.

6.3.3.2 Approaches to learning and academic performance for Group B_2

Given that the overall sample size for each of the three intermediate chemistry courses is small and few students present in each of the quadrants, the analysis related to the impact of varying approaches to learning on academic performance will only be explored at the full cohort level (see Table 6.9). To analyse students' academic performance, the pre-learning quiz score, end of semester examination and overall theory course performance were used.

6.3.3.2.1 Academic performance of varying approaches to learning for Group B_2

The cohort data revealed that students in Q_2 performed better in the pre-learning quizzes. Students in Q_1 performed better in the end of semester examination and overall theory course performance (see Table 6.9). A one-way ANOVA, however, showed no significant differences in academic performance for students in the pre-learning quiz score, end of semester examination and overall theory course performance when comparing the three approaches to learning as identified in the four quadrants.

Table 6.9. Academic performance of Group B_2 across the varying approaches to learning quadrants.

		Pre-learning quiz		End of semester examination		Overall theory course performance	
	n	M	SD	M	SD	M	SD
Q_1	16	86.56	22.12	72.68	17.96	56.34	11.61
Q_2	11	98.18	6.03	60.99	19.56	50.72	11.03
Q_3	8	95	7.56	64.49	19.82	52.55	11.47
Q_4	13	92.69	12.35	53.83	26.02	45.65	16.68

Note. M = mean, SD = standard deviation. Q_1 = HDA & LSA, Q_2 = HDA & HSA, Q_3 = LDA & LSA and Q_4 = LDA & HSA, HDA = high deep approach, LDA = low deep approach, HSA = high surface approach, LSA = low surface approach.

6.3.3.3 Observational case studies for Group B_2

6.3.3.3.1 Case study 1

Based on the R-SPQ-2F questionnaire, the participant self-identified as HDA and LSA. From the observational session, the participant's behavioural pattern was BP_3. The participant accessed both pre-learning materials once.

During the observation, the participant displayed characteristics of deep learning when accessing the pre-learning materials. While watching the video, the participant paused at multiple intervals and made some notes. During their quiz attempt, the participant would read each question and solve it on a notepad. Once an answer was selected, the participant referred to the video notes to confirm their answer before submitting it.

The participant explained that they like to become familiar with the concepts addressed and the notes are helpful "*to get background knowledge of what will be covered that week* ". The participant also highlighted that the summary notes made from the videos "*are there if I need them for revision*". The participant accessed the quiz after the video to relate the ideas and make an informed selection of their answer. The participant did not use the feedback provided as selected answers were correct throughout their quiz attempt. In other weeks, they stated that "*I add the feedback from the questions I did not get right to my notes just in case I need them later*". This is indicative of a deep approach as the participant is actively looking for patterns and underlying principles across the various learning resources.

6.3.3.3.2 Case study 2

Based on the R-SPQ-2F questionnaire, the participant self-identified as LDA and LSA. From the observational session, the participant's behavioural pattern was BP_1. The participant accessed the quiz 15 times.

During the observation, the participant displayed characteristics of surface learning when accessing the quiz. In the first 13 attempts, no clear pattern was noted in the participant's attempts with them stopping at random intervals once they had answered a couple of questions incorrectly. In the 14th attempt, the participant thoroughly completed the quiz answering all the questions. In their last attempt, the participant completed all the quiz questions and made some reference to the feedback provided. This is indicative of a surface approach as the participant was attempting to complete the quiz by simple trial and error without reflecting on the questions.

The participant explained *"I try to learn by repeating them, you know it is easy to check the answers, so I try to remember which one I got wrong".* They also noted that they dedicate a small amount of time to complete the quiz *"I have other things to do so I don't spend a lot of time on them and by the end I am happy with any mark it is better than not doing them".*

6.3.3.3.3 Case study 3

Based on the R-SPQ-2F questionnaire, the participant self-identified as HDA and HSA. From the observational session, the participant's behavioural pattern was BP_2. The participant accessed the video once and attempted the quiz three times.

During the observation, the participant displayed characteristics of both surface and deep learning when accessing the quiz. The participant initially viewed the video and left it open in the background while attempting the first quiz. From this, the participant wrote down which segments of the videos related to the quiz questions. It was observed that the student would also write down the feedback from questions irrespective of their selected answer.

During the next quiz attempts, the participant referred to the notes from the videos and the feedback from the first attempt. After the second quiz attempt, the participant added a few additional points before their final quiz attempt. In their last quiz attempt, the participant refereed to all the notes they had before selecting an answer. The participant explained that they like to refer to their notes *"gives you good tips that you can use"*. The participant found that accessing the video in this way allows them to *"I can focus on which part of the video I need to focus on instead of looking at it first"*.

6.3.3.4 Behavioural engagement and approaches to learning

Students' behavioural engagement (as identified in Chapter 4) was classified as adopting either a deep or surface approach to learning based on their displayed behavioural pattern (as identified in Chapter 5). Several hypotheses were proposed to relate students' self-identified approach to learning with their level of engagement and displayed behavioural pattern (see Table 6.10). These hypotheses were also informed by the data gathered from students' observational sessions and follow-up interview responses.

Students' self-identified approaches to learning were correlated with their levels of engagement (low, moderate, and high). While students of varying levels of engagement could have self-identified as any approach to learning, some general assumptions were made based on the contextual nature of the reported partially flipped learning model. It was proposed that higher levels of engagement would be associated with an increased tendency towards adopting a deep approach to learning.

Students' self-identified approaches to learning were also correlated with their behavioural patterns (BP_1 to BP_6). The criteria used was highly context specific, and students' behavioural patterns were classified based on the assumption that they were expected to complete both pre-learning materials. For instance, it was assumed that those who displayed BP_1 would be highly surface in their approach to learning as repeating the quiz multiple times without engaging with the video would be indicative of them relying on the ability to repeat questions as many times as they liked as part of the design of the quiz. However, if BP_1 was analysed with reference to students' engagement with only the quizzes without considering the videos, this behavioural pattern could be reflective of any self-identified approach and may not necessarily be indicative of a surface approach. This might be the case for several assumptions proposed in the subsequent section. It is essential to emphasise that these assumptions were made on the basis that the preferred behavioural pattern is for students to access both pre-learning materials.

Students who displayed BP_2 are classified as having a surface approach towards their learning as they opted to attempt the quiz more frequently than the pre-learning videos. It was assumed that although these students watched the videos, they relied on the ability to repeat questions in the quiz. Students who displayed BP_3 are classified as having a deep approach towards their learning; they accessed both pre-learning materials equally. Students who displayed BP_4 are classified to have a highly deep approach towards their learning as they choose to access the videos more than the quizzes, which implies they were gathering information from the videos rather than relying on repeating questions in the quiz. Students who displayed either BP_5 or BP_6 were not classified in terms of their approach to learning as BP_5 was not reflected in the data and since BP_6 reflects no interaction with any of the pre-learning materials, it was not feasible to distinguish whether these students adopted a surface or deep approach towards their learning, so they were classified as unengaged.

Table 6.10. Behavioural pattern link with approaches to learning.

Behavioural pattern	Behavioural type	Description	Approaches to learning
Q	BP_1	Quiz was only accessed	Highly Surface
Q>V	BP_2	Quiz was more frequently accessed when compared to the video	Surface
Q=V	BP_3	Quiz was equally accessed to the video	Deep
V>Q	BP_4	Video was more frequently accessed when compared to the quiz	Highly Deep
V	BP_5	Video was only accessed	-
N/A	BP_6	Neither of the quiz or video were accessed	Unengaged

Note. Q = quiz, V = video.

6.3.3.4.1 Difference in academic performance of varying approaches to learning across engagement groups

Students were categorised into three groups according to their level of engagement (as identified in chapter 4). Table 6.11 and Table 6.12 show the distribution of approaches to learning. Of the students in the study, the majority were highly engaged (n = 24) with the remaining moderately engaged (n = 14) or low engaged group (n = 10).

For the low engaged group, students who were classified to be strategic in their learning (i.e., identified in Q_3) performed better than those that adopted a deep or surface approach in the pre-learning quiz, end of semester examination and overall theory course performance. A one-way ANOVA, however, showed no significant differences in academic performance of low engaged students in the pre-learning quiz, end of semester examination and overall theory course performance when comparing the three approaches to learning as identified in the four quadrants.

For the moderately engaged group, students who were classified to be strategic in their learning (i.e., identified in Q_3) performed better than those that adopted a deep or surface approach in the pre-learning quiz. Students who were classified to have a deep approach (Q_1) performed better than the rest in the end of semester examination and the overall theory course performance. A one-way ANOVA, however, showed no significant differences in academic performance of moderately engaged students in the pre-learning quiz, end of semester examination and overall theory course performance when comparing the three approaches to learning as identified in the four quadrants.

For the highly engaged group, students who were classified as strategic in their learning (i.e., identified in Q_2) performed better than those that adopted a deep or surface approach in the pre-learning quiz. Students who were classified to have a deep approach (Q_1) performed better than the rest in the end of semester examination and the overall theory course performance. A one-way ANOVA, however, showed no significant differences in academic performance of highly engaged students in the pre-learning quiz, end of semester examination and overall theory course performance when comparing the three approaches to learning as identified in the four quadrants.

Table 6.11. Distribution of students' R-SPQ-2F questionnaire self-identified approaches to learning on a cohort level across engagement groups for Group B_2.

		Deep approach	Strategic approach		Surface approach
	n	Q_1	Q_2	Q_3	Q_4
LE	10	5	-	2	3
ME	14	3	3	3	5
HE	24	8	8	3	5
Total	48	16	11	8	13

Note. Q_1 = HDA & LSA, Q_2 = HDA & HSA, Q_3 = LDA & LSA and Q_4 = LDA & HSA. HDA = high deep approach, LDA = low deep approach, HSA = high surface approach, LSA = low surface approach. LE = low engagement, ME = moderate engagement, HE = high engagement.

Table 6.12. Academic performance across the varying approaches to learning across varying engagement groups.

Low engagement		Pre-learning quiz		End of semester examination		Overall theory course performance	
	n	M	SD	M	SD	M	SD
Q_1	5	65	29.58	65.51	18.22	49.46	9.37
Q_2	0	-	-	-	-	-	-
Q_3	2	85	7.07	68.89	11.11	54.39	5.40
Q_4	3	80	17.32	40.38	32.97	36.88	22.31

Moderate engagement							
	n	M	SD	M	SD	M	SD
Q_1	3	96.27	5.77	66.19	20.93	54.18	12.80
Q_2	3	93.33	11.55	40.53	14.64	38.40	6.41
Q_3	3	100		47.39	21.25	42.51	12.06
Q_4	5	93.00	10.95	46.65	28.24	41.03	17.05

High engagement							
	n	M	SD	M	SD	M	SD
Q_1	8	86.56	22.12	72.68	17.96	56.34	11.61
Q_2	8	98.18	6.03	60.99	19.56	50.72	11.03
Q_3	3	95	7.56	64.49	19.82	52.55	11.47
Q_4	5	92.69	12.35	53.83	26.02	45.65	16.68

Note. M = mean, SD = standard deviation, Q_1 = HDA & LSA, Q_2 = HDA & HSA, Q_3 = LDA & LSA and Q_4 = LDA & HSA, HDA = high deep approach, LDA = low deep approach, HSA = high surface approach, LSA = low surface approach.

6.3.3.4.2 Difference in academic performance of varying approaches to learning across behavioural groups

Students were categorised into their behavioural pattern groups (as identified in Chapter 5). Table 6.13 and Table 6.14 show the distribution of approaches to learning. For the students analysed, the majority adopted BP_2 (n = 24) meaning they accessed the quiz more frequently than the videos. The remaining students adopted BP_3 (n = 7); they accessed the pre-learning materials equally. There was one student in each of the remaining behavioural pattern groups (BP_1, BP_4 and BP_6). A one way-ANOVA was carried out only for BP_2 and BP_3 as the remaining behavioural pattern group sample sizes did not allow for statistical analysis.

Students who adopted BP_2, and self-identified to use a strategic approach in their learning (i.e., identified in Q_2) performed better in the pre-learning quiz when compared to the remaining self-identified approaches. Students who were classified to have a deep approach (Q_1) performed better than the rest in the end of semester examination and overall theory course performance. One-way ANOVA results, however, showed no significant differences in academic performance for students who adopted BP_2 in the pre-learning quiz, end of semester examination and overall theory course performance when comparing the three approaches to learning as identified in the four quadrants.

Students who adopted BP_3, and self-identified to use a strategic approach in their learning (i.e., identified in Q_2) performed better approach in the pre-learning quiz, end of semester examination and overall theory course performance when compared to students who adopted a deep or surface approach. One-way ANOVA results, however, showed no significant differences in academic performance for students who adopted BP_3 in the pre-learning quiz, end of semester examination and overall theory course performance when comparing the three approaches to learning as identified in the four quadrants.

Table 6.13. Distribution of students' R-SPQ-2F questionnaire self-identified approaches to learning on a cohort level across engagement groups for Group B_2.

		Deep approach	Strategic approach		Surface approach
	n	Q_1	Q_2	Q_3	Q_4
BP_1	1	1	-	-	-
BP_2	38	9	10	6	13
BP_3	7	4	1	2	-
BP_4	1	1	-	-	-
BP_5	0	-	-	-	-
BP_6	1	1	-	-	-

Note. Q_1 = HDA & LSA, Q_2 = HDA & HSA, Q_3 = LDA & LSA and Q_4 = LDA & HSA. HDA = high deep approach, LDA = low deep approach, HSA = high surface approach, LSA = low surface approach, BP = behaviour pattern where BP_1 = Q, BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_5 = V, BP_6 = N/A, where Q represents frequency of quiz access and V represents frequency of video access.

Table 6.14. Academic performance across the varying approaches to learning across varying engagement groups.

		Pre-learning quiz		End of semester examination		Overall theory course performance	
BP_2	*n*	M	SD	M	SD	M	SD
Q_1	9	93.89	11.67	69.04	19.88	55.10	12.88
Q_2	10	98	6.33	59.30	19.76	49.78	11.14
Q_3	6	95	8.37	65.83	22.87	53.09	13.18
Q_4	13	92.69	12.35	53.83	26.02	45.65	16.68
						-	
BP_3	*n*	M	SD	M	SD	M	SD
Q_1	4	85	9.15	71.51	18.43	54.83	13.18
Q_2	1	100		77.89		60.18	
Q_3	2	95	7.07	60.49	9.62	50.94	6.71

Note. Q_1 = HDA & LSA, Q_2 = HDA & HSA, Q_3 = LDA & LSA and Q_4 = LDA & HSA. HDA = high deep approach, LDA = low deep approach, HSA = high surface approach, LSA = low surface approach, BP = behaviour pattern where, $BP_2 = Q > V$, $BP_3 = Q = V$, where Q represents frequency of quiz access and V represents frequency of video access.

6.3.3.4.3 Distribution of behavioural pattern across the engagement groups for Group B_2

The distribution of behavioural patterns across the three engagement groups is presented in Table 6.15. The dominant behavioural pattern across the three engagement groups was a surface approach towards learning as indicated by the adopted behavioural pattern BP_2.

Table 6.15. Distribution of behavioural pattern across the engagement groups.

	LE	ME	HE
BP_1	1	-	-
BP_2	7	13	18
BP_3	1	1	5
BP_4	-	-	1
BP_6	1	-	-
Total	10	14	10

Note. $BP_1 = Q$, $BP_2 = Q > V$, $BP_3 = Q = V$, $BP_4 = Q < V$, $BP_5 = V$, BP_6 = N/A, where Q represents frequency of quiz access and V represents frequency of video access, HE = high engagement, ME = moderate engagement, LE = low engagement.

6.4 Discussion

6.4.1 Students' approaches to learning in the online component of a partially flipped learning model

This chapter explored students' self-identified approaches to learning as measured by the R-SPQ-2F questionnaire and its relationship with academic performance. Initial analysis comparing cohort level responses for Group A and Group B_2 revealed that the mean scores for students on the DA scale of the two main scales of the questionnaire were significantly higher than for those on the SA scale. A recent study analysing life science students' approaches to learning also showed significantly higher DA scores when compared to SA scores, which generally implied that students preferred to adopt an approach to learning that is more focused on understanding the course material than the course grade (Leiva-Brondo et al., 2020).

Another study on students' approaches to learning in a flipped learning model (Jeong et al., 2019) also using the R-SPQ-2F questionnaire found that by the end of the semester students had a general inclination towards a deep approach, as the number of students adopting a DA to learning increased whereas those that adopted a SA to learning decreased. Although similar findings are reported here, it should be noted that Jeong's et al. (2019) results were based on comparing students' questionnaire responses pre-and post-course completion. The findings described here did not quantitively examine changes in students' approaches to learning over the duration of a course. One of the factors that led to the shift in students' approach to learning was suggested to be related to the course design, specifically the teaching and learning resources embedded in the flipped learning environment (Zeegers, 2001).

Nijhuis et al. (2008) found that, within the same cohort of student, there are two clusters; one that is fixed in their adopted approach and is not influenced by changes in their learning environment and another that might easily adapt and respond to changes. This indicates that the course design of the partially flipped learning model might not necessarily influence the learning approaches of all students, but it may partially guide some to adopt a particular approach. Preliminary qualitative data will be presented in subsequent sections in the form of observational case studies supported with student interviews to examine the link between students' self-identified approach and their implemented learning approach. This has practical implications for future research as it helps to better understand the degree in which the partially flipped learning model may influence students to adopt a particular approach, the motivating factors behind students' adopted approach, and how their learning strategies may impact their academic performance.

Further analysis at a course level showed no significant differences for the main DA scales but significant differences were observed for the main SA scale. The mean score of Group A for the main SA scale was significantly higher for the fundamentals course when compared to the mainstream course. The mean score of Group B_2 for the main SA scale was significantly higher for the mainstream course when compared to the advanced course. One of the possible explanations for the observed differences may also be related to individual differences, such as students' academic ability and their prior knowledge of chemistry. In Group A, students enrolled in the fundamentals course generally have no to minimal chemistry background compared to those in mainstream course who would have at least completed senior high school chemistry. Similarly, in Group B_2 students enrol in the different intermediate chemistry courses based on their previous academic performance in the junior courses. Students in the advanced course are perceived to have a stronger chemistry background when compared to those in the mainstream course. This may partially explain the relatively high SA scores observed in the chemistry courses where students' background knowledge is relatively weaker than the remaining courses.

The sub-scale that contributed to the observed course differences in the main SA scale was the surface strategy, which refers to the learning methods used by the students (Biggs, 1993). These results, in conjunction with the differences observed in the main SA scale, suggest that a potential contextual factor that may have influenced the adopted approach is related to course design. Since the same online pre-learning materials were used across the different chemistry course levels, they might not have catered for the varying learning needs of the students. Another possible factor is the question format of the pre-learning quizzes. The nature of the questions embedded in the quizzes may have influenced students' adopted approaches along a continuum of cognitive thinking requirements, where simple factual recall questions may encourage the adoption of a surface approach whereas evaluating questions may support a deep approach.

Socha and Sigler (2014) propose that students need support in selecting which strategy to adopt in their learning. Thus, guidance and explicit instructions embedded in the learning environment are necessary for developing students' learning strategies and encouraging them to opt for deep learning (Leiva-Brondo et al., 2020). While students in the reported partially flipped learning model were instructed to complete the pre-learning materials by the end of each week, no further data was collected to examine this further.

To encourage students to adopt a deep approach towards learning future implementation of the courses should consider; (1) providing a range of appropriate online pre-learning material to better suit the learning needs of all the students and (2) inclusion of a post-learning quiz. This may be achieved by adjusting the complexity of the quiz, through a range of levels of questions (Bloom's Taxonomy) or a variety of quiz formats. Limited research has reported on the use of a post-learning quiz, it has been suggested that it may be used as an additional learning resource to 'link' the knowledge presented during the in-class session before engaging in the next set of pre-learning activities (O'Flaherty & Philips, 2015).

Comparison of individual students' DA and SA distribution scores revealed that the largest group self-identified to be strategic learners, with 39% in Group A and 40% in Group B_2. The remaining students self-identified as adopting a deep approach (Group A: 31% Group B_2: 33%) or a surface approach (Group A: 30% Group B_2: 27%). This is consistent with previous research that holistically examined students approach to learning a flipped classroom which indicated that students who adopted a strategic approach tend to combine surface and deep learning strategies (Leiva-Brondo et al., 2020). It has been proposed that students alternate between DA and SA approach depending on the characteristics of the task (Jovanović et al., 2017). Generally, students interact with the online pre-learning material in a surface manner to facilitate a deep approach when they engage with the active in-class learning material (Sigurôardóttir & Heijtra, & 2020). Although the findings reported in this thesis focus on students approaches to learning towards the online pre-learning material, similar inferences for this model can be drawn. Students who self-identified to be strategic learners may have, in each week, interacted with the online pre-learning material in either a surface or deep manner. Although the results presented in this thesis do not provide adequate evidence to support the proposition that a partially flipped learning model promotes a deep approach and active learning opportunities (Danker, 2015; McLean et al., 2016), it appears that the online pre-learning materials enabled the adoption of either a deep, surface or a strategic approach towards learning depending on the students' self-identified preference.

Further investigations, including weekly observations or weekly self-reflections, would be useful to better understand why students chose a certain approach, and to determine if the weekly chemistry concepts delivered in the pre-learning material may have encouraged them to alter their approach. It can also provide valuable insight on how the pre-learning materials can help develop students' metacognitive skills, which can enhance their learning experience in a flipped learning environment (Limueco & Prudente, 2019). Another potential factor that may have influenced the distribution of the approaches to learning is that students may not have perceived that the online pre-learning material required deep learning, so a surface or strategic approach may have been considered sufficient to achieve the desired outcomes. Subsequent sections will explore how students' online behavioural engagement level and their exhibited behavioural pattern differ across the various self-identified approaches to learning and how these relate to academic performance.

When analysing the relationship between students' self-identified approach to learning and academic performance, significant differences were only observed on a cohort level in Group A. The lack of observed differences in Group B_2 may be related to the relatively small sample size with fewer students dispersed across the four quadrants. In Group A, the results showed that strategic learners performed significantly better in their quiz score when compared to surface learners. Students who self-identified to be strategic learners were mainly in Q_2 which suggests they combined both surface and deep learning strategies as indicated by their high mean score values for the DA and SA scales. Previous studies have predominately examined the relationship between students' learning approach and their overall academic performance rather than also considering other academic measures such as students' performance in the overall online pre-learning quizzes. Despite this, the meta-analysis by Richardson et al. (2012) found a small positive correlation between both deep and strategic approaches to learning and academic performance, with a surface approach observed to be negatively correlated with academic performance.

The results reported by Jeong et al. (2019), which also used the R-SPQ-2F questionnaire, revealed a positive correlation between the difference in the DA-SA scores and academic performance. These results, in conjunction with the findings presented in this thesis suggest that there is an association between the learning strategies that students self-identified and their academic performance. However, further research is warranted to observe these trends on a larger scale to be able to draw inferences on the effect of learning approach across a range of academic measures in a partially flipped learning model.

Comparison of students' self-identified approach to learning with their displayed behavioural pattern, supported by their self-described approach obtained from their interview responses, provided valuable qualitative insight to corroborate *how* students approach the online component of the partially flipped learning model and the reasons behind their learning strategies. From the observational case studies conducted in Group A (n = 6), the two cases who self-identified to adopt a deep approach displayed deep learning behavioural as identified by their behavioural pattern (BP_2) and supported by their interview responses. The two cases who self-identified to adopt a strategic approach, displayed both deep and surface strategies towards their learning. For the two cases who self-identified to adopt a surface approach, one displayed a surface learning preference whereas the other displayed a deep approach towards their learning. From the observational case studies conducted in Group B_2 (n = 3), each of the three cases displayed their self-identified approach in their learning behaviour with the online pre-learning material.

These findings are consistent with Hamm and Robertson (2010) who also compared students self-identified learning preference for a multimedia assessment. Whilst no clear inferences were drawn, it was suggested that students adopted both deep and surface learning strategies based on their personal preferences instead of adopting a deep approach as originally intended. As reported from their interviews, the findings here provide some insight on the range of factors that contribute to a student's adopted approach. Generally, students who self-identified to adopt a deep or surface approach clearly articulate the motivating factors behind their approach which mainly reflected their intrinsic motivation towards learning, for example, gaining a foundational understanding prior to attending the in-class session or a revision tool to consolidate and refine conceptual knowledge. Of those who adopted a surface approach, some did not perceive the pre-learning material to be useful whilst others interact with them to merely receive the associated grades.

The motivating factors for students who self-identified to be strategic learners combined some of the factors above but also highlighted that the nature of the chemistry concepts delivered in the weekly pre-learning material influenced their adopted approach. Similar findings from the interview responses, were reported by Hamm and Robertson (2010) which also provided students with a description of the characteristics of surface and deep leaners prior to the interviews, to ensure that students were consistent in describing their approach to learning. Future investigations using interview methods reported by Hamm and Robertson (2010) could ensure that students responses are semi-structured whilst also providing them the opportunity to expand and justify the reasons behind their adopted approach. To further understand why students chose their self-identified approach and its relationship with their self-described approach, it may also be worth investigating how the same student approaches the online pre-learning material at different intervals over the course of the semester rather than conducting one observational session that could have been influenced by the nature of the weekly chemistry concepts. In addition, future investigations could examine a larger sample of students to gain a better understanding of the diverse learning strategies adopted by students of varying DA and SA responses.

6.4.2 Comparison of students' identified approach to learning with their behavioural engagement and behavioural pattern with the online component and its impact on academic performance

Comparison of students' self-identified approach to learning (deep, strategic, or surface) with respect to the students' (1) engagement level (low, moderate, and high) and (2) behavioural pattern (BP_1 to BP_6) demonstrated that there are no significant differences in their academic performance as measured by their quiz score, end of semester examination and overall theory course performance. It was anticipated that higher levels of engagement would be associated with an increased tendency towards adopting a deeper approach to learning. This, however, was not the case. Instead, the data for Group B_2 revealed that low engaged students mainly self-identified adopting a deep rather than a surface approach to learning. The data also revealed that moderately and highly engaged students self-identified as strategic in their learning. Although highly engaged students classified to be strategic rather than deep learners, most were categorised in Q_2 as having high scores across both the DA and SA scales.

The results presented in this thesis are somewhat preliminary and highly context specific. Several factors may have contributed to the apparent lack of association between students' self-identified approach, their level of engagement, displayed behavioural pattern and their academic performance. The relatively small sample size of Group B_2 may prevent the findings from being extrapolated, therefore future research should increase the sample size to identify the significance of the observed changes and to potentially draw any causal links between the various parameters. The observational case studies discussed in Section 6.4.1 provided a limited but valuable insight into *why* these students may have self-identified for a particular approach to learning and *how* it related to their behavioural engagement. The students' engagement level did not align with the predicted learning approach. Instead, the results in general revealed that students with higher levels of engagement tend to favour adopting a strategic approach towards learning.

Extensive research suggests that engagement can influence students approaches to learning and lead to improved academic performance (Floyd, Harrington, & Santiago, 2009; Hava, 2021; Lee et al., 2018). Whilst no significant change in academic performance was detected between students' self-identified approaches to learning and engagement level, previous findings discussed in Chapter 4 revealed that higher levels of engagement with the pre-learning material led to significant improvements in academic performance and a reduction in failure rates. The findings reported in this thesis focused exclusively on behavioural engagement. Future research could explore the multi-dimensional nature of engagement as the affective, cognitive, and behavioural constructs are intertwined and may affect different aspects of students learning outcomes (Floyd et al., 2009; Lee et al., 2018). Lee et al. (2018) found several relationship pathways between engagement and learning outcomes and proposed that affective engagement directly effects learning outcomes and indirectly affects them through cognitive and behavioural engagement. Their results, in conjunction with those of Floyd et al. (2009), reveal that perceived course value is a leading affective factor that can influence students' behavioural engagement (their level of interaction with the learning material) and their cognitive engagement (the effort they are willing to exert in the learning process). Students who perceive the learning materials to be relevant, meaningful, and closely aligned with their personal learning goals are more likely to be motivated to engage with the assigned tasks, which can potentially lead to deep learning (Hava, 2021). However, these parameters may not necessarily directly relate to one another, as a student can be fully engaged yet may not find the course of value and might demonstrate their level of engagement by either using deep or surface learning strategies.

Biggs (1999) seminal work of "What the Student Does: teaching for enhanced learning*"* proposed that students' level of engagement is influenced by a two-way interaction between the learning activities embedded in the teaching method, and the students' academic orientation. As Figure 6.8 shows, 'academic' students will often display a deep approach towards learning as measured by higher levels of engagement irrespective of the teaching methods used. For 'non-academic' students, the teaching methods used can strongly influence their level of engagement and in turn their approach towards learning. Prior to the implementation of the partially flipped learning model described in this thesis, a large gap was observed in terms of level of engagement between students of varying academic orientation. As shown by Point A in Figure 6.8, 'academic' students are perceived to apply higher levels of Bloom's Taxonomy compared to 'non-academic' students. The intention of the implementation of the partially flipped learning model was to narrow the gap between these students and shift students irrespective of their academic orientation to apply higher levels of engagement (i.e., to Point B). The online pre-learning materials in the present study were designed to provide students with the foundational knowledge required for the in-class sessions rather than to promote a particular approach to learning. Thus, students who displayed a passive approach towards the online pre-learning materials were still expected to engage deeply with the guided active learning activities embedded in the in-class sessions. In addition, although the online pre-learning material might be perceived to be passive in it is nature, it does not hinder students' ability to process the presented learning material in a deep manner. This further reflects the complexity of factors that may influence students' adoption of a particular approach towards learning.

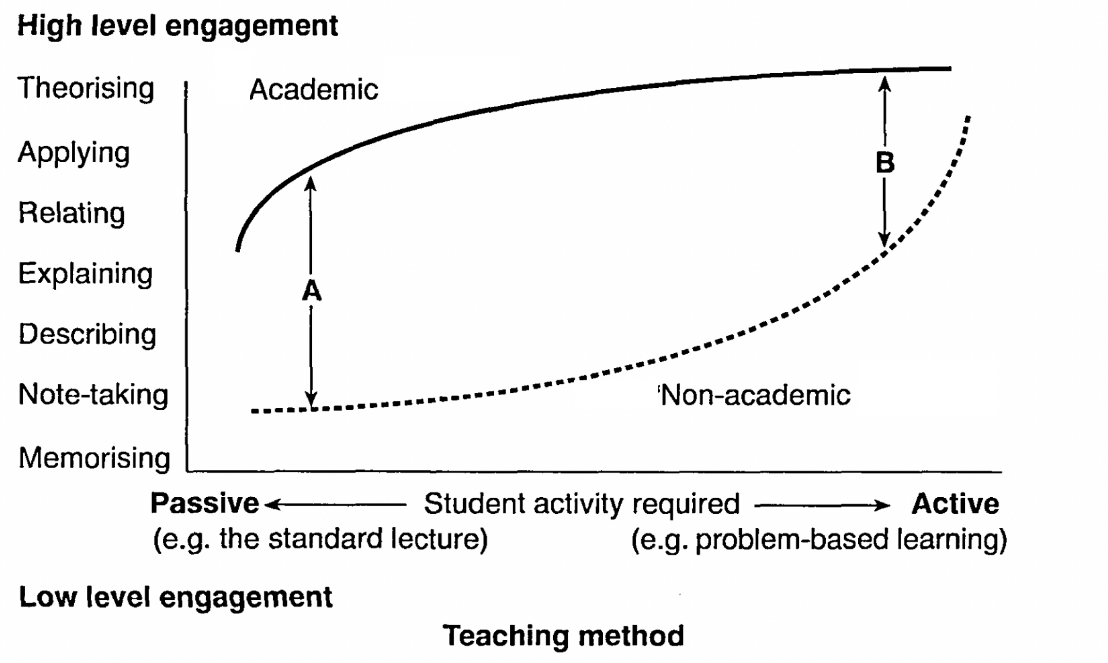

Figure 6.8. Student orientation, teaching method, and level of engagement (extracted from Biggs, 1990).

To further examine the relationship between students' self-identified approach to learning and their respective engagement levels, it was essential to analyse their displayed behavioural pattern with the online pre-learning materials. The data revealed that irrespective of the students' self-identified approach to learning, the dominant behavioural pattern adopted across all three engagement levels was BP_2. This finding does not align with the original assumptions proposed as it was anticipated that students with a deep approach to learning would display BP_3 or BP_4. These behavioural patterns reflect an increased tendency towards accessing the videos as students seek to extract knowledge and examine their conceptual understanding by completing the quizzes. Students with a surface approach to learning were expected to display BP_1 or BP_2. These behavioural patterns reflect a tendency towards accessing the quizzes. These students may be relying on the mastery nature of the pre-learning quizzes and opted to frequently access them in hope of attaining desirable results without accessing or minimal access to the videos. The data also showed that irrespective of the displayed behavioural pattern, no significant differences were detected in their academic performance across the different self-identified approach to learning.

In addition to the previously discussed factors, the design of the online pre-learning materials: the pre-learning quizzes and videos may have influenced the adopted approach. The dominant behavioural pattern BP_2 observed may have been related to the format and the nature of the questions of the quizzes. Since the format mainly consisted of single best answers, short answer questions, and drag and drop questions, it may have encouraged students to adopt a surface rather than a deep approach. Future versions may instead include extended response questions where students can demonstrate their ability to apply the knowledge they have acquired instead of simple factual recall of information.

The observed results may also in part be attributed to the novel approach used for categorising students' level of engagement based on their Engagement Index score (as discussed in Chapter 4). The methodology used for the construction of the Engagement index may need further refinements to better encompass students' individual differences. For example, follow up interviews may be used to elicit reasons behind students' behavioural engagement with the online pre-learning material, particularly those students who were categorised with low engagement but still had a high academic standing. This might help identify whether students were indeed engaged and, if they were engaged, what changes should be considered for the construction of the Engagement Index. Moreover, categorising the six behavioural patterns as indicators of either a surface or deep approach was subjective and based on the assumptions that students would be expected to engage with both pre-learning materials. Thus, a student who displayed BP_1 because they only completed the quiz was considered to have a surface approach but, in fact, they might have adopted a deep approach whilst solely completing the quiz. The methodology used to categorise students self-identified approach to learning across the four quadrants may need further refinement. The boundary values for each of the quadrants were based on the overall mean average scores obtained from all the students across the DA and SA scores. Individual students were then categorised in one of these four quadrants based on that criterion; perhaps further refinement is needed to better reflect individual students' self-identified learning approach.

Chapter 7: Conclusion

7.1 Brief introduction

The studies presented in this thesis investigated second year students' online behavioural engagement, behavioural pattern, and approaches to learning with the online component of a partially flipped learning model and its impact on students' academic performance in intermediate chemistry courses. This thesis also explored how students' behavioural engagement, behavioural pattern, and approaches to learning are interrelated with one another. While the focus of this thesis was intermediate chemistry courses, parallel data were collected from junior chemistry courses to assess potential similarities or differences with intermediate courses regarding students' approaches to learning. This chapter provides a summary of the research studies, implications of the research findings, and outlines limitations and recommendations for future research in implementing a partially flipped learning model.

7.2 Summary of the research studies

7.2.1 Behavioural engagement

Chapter 4 developed an engagement index to quantify students' online behavioural engagement levels with the pre-learning materials of a partially flipped learning model. Students' level of engagement (low, moderate, and high) was based on their engagement index derived from their varying levels of interactions with five engagement index parameters related to the pre-learning videos and pre-learning quizzes. For the intermediate cohort, higher levels of engagement with the online pre-learning materials led to significant improvements in the end of semester examination and overall theory course performance. The most pronounced statistically significant differences in academic performance were observed across the three levels of engagement for students in the mainstream courses (CHEM2401/CHEM2402). Some statistically significant variations in academic performance were found in the advanced courses (CHEM2911/CHEM2912) across the three levels of engagement whereas no statistically significant differences were noted in the SSP courses (CHEM2915/CHEM2916). The observed differences in academic performance may in part be related to students' motivation, proficiency levels and the instructional design of the online pre-learning materials.

The results on a cohort and course level showed that students' behavioural engagement had a positive effect on academic performance at the end of each semester. However, no significant differences were observed when comparing academic performance across both semesters, although it should be noted that the course material covered in the two semesters is quite different. Further analysis on a sub-group of students that had completed the intermediate chemistry courses in both semesters, revealed no clear patterns as to how changes in students' behavioural engagement across semesters affected their academic performance.

7.2.2 Behavioural pattern

Chapter 5 further expanded on students' online behavioural engagement by exploring students' distinct behavioural patterns with the pre-learning materials. For the intermediate cohort, higher levels of interaction with both pre-learning materials were detected for the second semester course when compared to first semester. Comparison of the three chemistry courses revealed that students in the mainstream courses (CHEM2401/CHEM2402) tended to access the online pre-learning materials more frequently than those in the advanced courses (CHEM2911/CHEM2912) and SSP courses (CHEM2915/CHEM2916).

For the intermediate cohort, there was a positive association between changes in the degree of students' interaction (none, partially, or fully) with the online pre-learning materials and their academic performance. Interacting with all the pre-learning materials positively impacted students' academic performance. More specifically, students who had a tendency towards accessing most of the assigned videos performed better in the pre-learning quizzes but not necessarily on the in-semester quiz and end of semester examination performance. In contrast, accessing most of the pre-learning quizzes positively impacted students' performance in the in-semester quizzes and end of semester examination. These results reveal the potential effects a partially flipped learning model can have on students' learning and academic performance.

Although students varied their weekly behavioural pattern during the semester, the overall dominant behavioural pattern was one where students accessed the pre-learning quiz more frequently than the pre-learning video (BP_2). Those that accessed the videos equally (BP_3) or more frequently (BP_4) than the quizzes performed better than the remaining observed behaviours. In contrast, those students who displayed BP_2 performed lower than those who displayed the other behavioural patterns. No clear pattern, however, was observed when comparing students' overall behavioural pattern with their academic performance in the pre-learning quizzes, end of semester examination and overall theory course performance. Instead, there was an increased trend towards accessing the videos more frequently in the second semester than first semester. This resulted in differences being observed in the performance of the overall pre-learning quiz scores when compared to the dominant behavioural pattern BP_2.

Comparison of students displayed behavioural pattern (BP_1 to BP_6) with respect to their engagement level (low, moderate, and high) revealed that there were no significant differences in end of semester examination and overall theory course performance, however, trends were noted in the pre-learning quiz performance. The cohort data for both Groups B_1 and B_2 showed that moderately and highly engaged students that displayed BP_2 performed significantly better in the pre-learning quizzes when compared to the remaining behavioural pattern groups. Furthermore, the most prominent differences were observed in the low engaged students, were those that adopted BP_2 in Group B_1 and BP_1 in Group B_2 for the first semester, and BP_2 across both groups for the second semester performed significantly better in the pre-learning quizzes when compared to the remaining behavioural pattern groups.

7.2.3 Approaches to learning

Chapter 6 examined students' approaches to learning with the pre-learning materials and how these varied across the different levels of engagement and behavioural patterns. For the junior and intermediate cohort, it was observed that students' self-identified deep approach (DA) scores were significantly higher than their surface approach (SA) scores. Comparison of the different chemistry courses showed no significant differences between the DA and SA scores, however, similar trends for the SA scale were detected across both chemistry groups. For junior chemistry courses, SA scores were significantly higher for the fundamentals course (CHEM1001) when compared to the mainstream course (CHEM1101). Similar trends were noted for the intermediate chemistry courses, where SA scores were significantly higher for the mainstream course (CHEM2401) when compared to the advanced course (CHEM2911).

Comparison of individual students' self-identified learning approach based on their DA and SA distribution scores across both groups revealed that the largest group self-identified to be strategic learners with the remaining students self-identified as deep or surface learners. Only strategic learners in junior chemistry courses, however, performed significantly better in the pre-learning quizzes when compared to surface learners. Furthermore, the observational case analysis showed that students' self-identified approach to learning does not necessarily support their self-described approach as noted from their interview responses.

Comparison of students' self-identified approach to learning with respect to the students' engagement level and behavioural pattern demonstrated no significant differences in their academic performance. Despite this, the results revealed that students with higher levels of engagement tended to favour adopting a strategic approach towards learning. Moreover, the dominant behavioural pattern adopted across the various self-identified approaches to learning was BP_2 which reflects students' tendency to favour accessing the quizzes more frequently than the videos.

7.2.4 Students' perceptions of the pre-learning materials

Overall, students perceived the online pre-learning material of the partially flipped learning model to positively impact their learning experience. They reported that the main motivating factor behind accessing the videos was to enhance their performance in the quiz and that the quizzes are perceived to be 'easy' marks that contribute to their overall course performance. Furthermore, students' responses reflected the perceived benefits of the pre-learning materials, particularly the flexibility it offered them in their learning and the coherent link between the videos and quizzes. Some students stated that the pre-learning materials were suited to their level whilst others requested the quizzes to include harder applications. Another feature that students appreciated was the feedback mechanism embedded in the quizzes and requested additional hints and prompts to be embedded to further support their learning needs.

7.3 Implications of the research findings

The present study supports existing claims that engagement with the online pre-learning materials of a partially flipped learning model has the potential to improve academic performance (Cormier & Voisard, 2018; Lee et al., 2018; Wang 2017; Wang 2019; O'Flaherty & Phillips, 2015; Seery, 2015). The use of learning analytics offers an alternative approach for measuring students' online behavioural engagement in real-time, expanding on existing frameworks and traditional research methods which are often limited by students' self-reported responses (Bond et al., 2020; Jovanović et al., 2017; Wang, 2019).

The developed behavioural engagement index contributes empirical evidence using learning analytics to quantify students' engagement levels based on their degree of interactions with five parameters related to the online pre-learning materials. This provides a more comprehensive understanding of how variation in students' engagement levels may impact their academic performance. Higher levels of engagement, as measured by the engagement index score, led to significant improvements in performance supporting the hypothesis Eichler and Peeples (2016) proposed that engagement with the online pre-learning materials is one of the leading factors behind the observed improvements in academic performance. Furthermore, the findings from the present study compliment the research by Wang (2017) who also reported a significant positive effect on academic achievement. A practical implication of the developed engagement index is that it may be used to detect students' online [dis]engagement and provide instructors with insightful data for personalised feedback (Ma, Han, Yang, & Cheng, 2015).

The findings from the current study suggest that student proficiency levels in a subject may be a contributing factor to the observed differences in academic performance across the various courses. This is consistent with Cormier and Voisard (2018) which revealed that "low-achieving" students, as categorised by their academic ability, were more engaged and performed significantly better in the final course grades when compared to "high-achieving" students. Similarly, Crimmins and Midkiff (2017) also noted improvements in learning outcomes for all students but those at the lowest academic achievement levels appeared to experience the most gains. However, a shortcoming of these studies is that they did not explicitly identify which component(s) of the flipped learning model may have contributed to the varying levels of engagement and differences in academic performance. The present study offers evidence that the 'reverse expertise effect' (Kalyuha et al., 2003) should be taken into consideration in the instructional design of a flipped or partially learning model to appropriately accommodate for varying student proficiency levels. The present study provides new insight towards student learning and curriculum design as the online pre-learning materials may have practical implications towards reducing the "achievement gaps" between students with varying proficiency in a course. One suggestion is to provide pre-learning materials with a range of difficulty. If there are multiple courses for a particular subject with different enrolment requirements, then it is important to ensure that the pre-learning materials for each course are designed to reflect the diverse student academic backgrounds.

The qualitative comments provide further support for students' perception that a flipped learning model offers a flexible learning environment (Long et al., 2016; Flynn, 2015; Seery, 2015). Students' explanations for their observed interaction with the online pre-learning materials demonstrated that they are aware of and appreciate the cohesive link between the various components (online and in-class) of the partially flipped learning model. This is important evidence to encourage thoughtful design of pre-learning material and engage student review and feedback on course resources. Students also noted that accessing the videos helped to improve their quiz performance and gain foundational knowledge needed for the in-class sessions. The main reason for accessing the quizzes, however, was the marks associated with the quizzes. This reinforces the concept that an incentive mark may be an extrinsic motivator for students to engage with pre-learning materials. The quizzes were also perceived to be an effective tool in offering individualised and personalised learning experience through the feedback mechanism embedded in them. Several students suggested additional hints and prompts should be embedded to further support learning needs. These findings align with O'Flaherty and Philips (2015) suggestion that students are more likely to engage with pre-learning materials if they include interactive features, provide formative feedback mechanisms, and are coherently linked to the in-class component. These are important considerations for curriculum design as the degree to which students interact with the online pre-learning materials may influence their level of preparedness, understanding and ability to engage with the learning activities presented during the in-class sessions and potentially impact their academic performance (Dooley & Makasis, 2020).

The present study adapted the approach suggested by Brennan et al. (2019) to cluster students' behavioural engagement into patterns based on measuring the frequency of access for each of the online pre-learning materials: videos and quizzes. While the identified behavioural patterns are highly context specific, the findings contribute to the existing research as the identified clusters of engagement are based on students' combined interaction with both pre-learning materials, rather than students' separate interaction with each (Long et al., 2019; Dazo et al., 2016; Lacher & Lewis, 2015; Lacher & Lewis, 2014). The identified clusters are well differentiated and suggest the presence of six distinct behavioural patterns. Based on the richness (frequency of displayed behavioural patterns) and the evenness (spread of behavioural patterns) matrix (Brennan et al., 2019), the dominant behavioural pattern over the course of a semester was BP_2 which showed that students tended to access the quizzes more frequently than the videos. The use of such a matrix enables tracing of both individual and cohort level changes in behavioural patterns. Instructors can also use this information to identify which periods during the semester students may shift away from rare behaviours to more common ones and intervene to encourage or inhibit certain behaviours. Furthermore, the dominant behavioural pattern BP_2 was observed across both semesters despite differences in level of difficulty and course material. It should be noted that the partially flipped learning model implemented at the time of this study was only applied to the chemistry courses. While students may have had some exposure to learning from this instructional design in junior chemistry courses, they may not have sufficiently developed their skills to self-regulate their learning and modify their existing learning strategies. Although self-regulated learning was not explicitly measured in this thesis, it may be another contributing factor that influenced students' engagement. In a flipped learning model, the optimum behavioural pattern is for students to access all the pre-learning materials, and in this case with a preference for accessing videos before quizzes. The instructional design of the pre-learning materials, specifically the mastery nature of the quizzes, may have prompted students to adopt BP_2. Many factors can affect student behaviour and be contributors to why significant differences in performance were noted for specific weeks. The main reason identified by students for completing the quizzes was that they contributed to their course grade. It may be that students focused on the academic gains rather than learning gains and opted to repeatedly access the quizzes in an effort to maximise their performance rather than focus on the perceived benefits of watching the videos. Students that accessed the videos revealed that their main motivation was to improve their academic performance in the quizzes followed by gaining a conceptual understanding of chemistry. It may be that proficiency level, familiarity with concepts, or level of difficulty of the weekly concepts also influenced the frequency of video-viewing access and, as such, their overall behavioural pattern. This highlights the complex nature of student learning and the importance for instructors to gain an understanding of students' learning needs. By reviewing the weekly quiz performance, instructors can better understand students' level of subject knowledge or preparedness and accordingly tailor in-class teaching and learning experience.

The existing findings extend those of Beatty et al. (2019) and Dazo et al. (2016) in which a positive relationship was observed between video-viewing behaviours and overall course performance. The current study focused on the degree of student interaction (none, partially, or fully) with each of the online pre-learning materials and their impact on various measures of academic performance. Students that watched all the assigned weekly videos had a significantly higher quiz score, but no noticeable differences were observed in the other course assessment. Completing all assigned pre-learning quizzes led to significantly higher performance in the in-semester quizzes and end of semester examination. Instructors may be able to examine not only the weekly effect of students' behavioural pattern but also how varying degree of interactions with each pre-learning material may affect different measures of course performance. This information can also be used to inform students of the benefits of adopting the desired behavioural pattern to improve their academic performance.

The present study also explored students' self-identified approaches to learning as measured by the R-SPQ-2F questionnaire to gain an understanding of the learning strategies adopted whilst accessing the online pre-learning materials and their impact on their performance. The junior and intermediate cohort responses align with previously reported studies using the same questionnaire in a flipped learning environment, where significantly higher DA scores compared to SA scores were observed (Leiva-Brondo et al., 2020; Jeong et al., 2020). Further analysis for the junior and intermediate courses revealed significant differences only in the main SA scales, specifically the surface strategy sub-scale of the questionnaire which refers to the learning methods used by the students (Biggs, 1993). Higher differences in the SA scores were observed in courses where students' proficiency level is relatively weaker than the other courses, suggesting that these differences may be attributed to a range of factors including student proficiency levels. This suggests the need for instructors to possess an initial understanding of students' self-identified approach as early as possible in the semester so informed changes can be made to help support students in selecting which strategy to adopt (Socha & Sigler, 2014). Instructors can address this with the inclusion of scaffolding to help develop students' self-regulation skills or provide individualised learning material to cater for the diverse learning needs (Kim et al., 2021). Another factor that instructors need to consider is the design of the online pre-learning materials. While the format of the quizzes and/or the question types (single best answer, short answer questions and drag and drop) embedded in this model were designed to target lower cognitive processing skills, increasing the skill range of the questions based on Bloom's Taxonomy may encourage students to adopt a deeper learning approach.

The present study extends current research on comparing students' self-identified approach and self-described approach to learning from self-reported interview responses (Hamm & Robertson, 2010) by including data gathered in observational sessions. It was possible to triangulate students' self-identified approach with their observed approach whilst completing one of the weekly pre-learning materials following an interview where they self-described their approach. Self-identified approaches did not necessarily align with the displayed and self-described approach, consistent with Hamm and Robertson (2010) research finding. In the current study, the main reason given by students that self-identified to be deep learners focused on the intrinsic value of the pre-learning materials, such as gaining foundational knowledge, whereas those that self-identified to be surface learners focused on the extrinsic reward of completing the quizzes with limited interaction with the video. Strategic learners, however, were conscious of the value of the pre-learning material whilst also prioritising other factors relevant to them such as time spent and other course requirements.

Comparison of students' DA and SA scores revealed that the largest group self-identified to be strategic learners in junior and intermediate courses. Strategic learners in junior courses performed significantly better than surface learners in the online pre-learning quizzes. Strategic learners identified the nature of the chemistry concept to be the main motivating factor influencing their adopted approach. This supports Nijhuis et al. (2008) claim that found within the same cohort of students, there can be two clusters; one that is fixed in their adopted approach and is not influenced by changes in their learning environment and another that might easily adapt and respond to changes. The latter would include strategic learners. The lack of significant results observed in the intermediate courses may in part be due to the relatively small sample size. Socha and Sigler (2014) propose that students need support in selecting which strategy to adopt in their learning. Although intermediate students would have experience with the flipped learning model from junior chemistry, it is possible that this experience did not transfer to second year. If this was the case, instructors could embed guided instructions to scaffold self-regulated learning skills so they can be better equipped to adjust their learning approach.

Although student motivation was not explicitly measured in the present study, it might be an underlying factor that influenced students' engagement, displayed behaviour, and adopted approach to learning with the pre-learning materials and resulted in the varying differences in academic performance. Applying a mark to the pre-learning quizzes in the mainstream and advanced courses but not in the SSP courses may have influenced students' intrinsic motivation through extrinsic means (Abeysekara & Dawson, 2015). The design of the online component in a flipped or partially flipped learning model should include materials that students perceive to be relevant, meaningful, appropriately challenging and closely aligned with their learning goals. This will more likely ensure that students will be motivated to engage and display behavioural patterns that are reflective of a deeper approach to learning.

7.4 Limitations and recommendation for future work

While the studies in this thesis contribute to current understanding of students' behavioural engagement, behavioural pattern, and approach to learning with the online component of a partially flipped learning model and measure this model's impact on academic performance in higher education chemistry courses, several limitations must be acknowledged with recommendation of future work.

The engagement index and behavioural patterns provide an alternative approach to quantifying students' online engagement and patterns with the pre-learning materials. The index, however, only provides a narrow understanding of students' engagement and retention of course material. Student levels of engagement were categorised based on a cumulative engagement index score derived from five parameters related to the pre-learning videos and pre-learning quizzes. Although these parameters were informed by the design of each of the pre-learning materials, statistical means were used to assign inter-limit values based on subjective assumptions made in relation to student engagement. The methodology used to develop the index may need further refinement to better encompass individual student differences. This may be achieved by incorporating qualitative methods, such as follow up interviews or focus groups, to elicit reasons behind students' behavioural engagement with the pre-learning materials. This could provide insight into students that were classified in the low engaged group but still had a high academic standing and those that were in the high engaged group but had a low academic standing. This also might help identify whether students were indeed engaged, and if they were engaged, what changes are needed to be considered for the [re]construction of the engagement index. The inclusion of qualitative measures may also provide insight regarding the reasons behind the variation in the frequency of access of the pre-learning material. They may also identify factors that influenced students to alter their weekly behavioural pattern over the course of a semester. These qualitative responses may also in part explain why low engaged students displayed BP_2, and how in their case accessing the quizzes more frequently than the videos led to significantly better academic performance than the remaining behavioural pattern groups.

The results revealed no clear pattern between how changes in students' online behavioural engagement across semester can affect their academic performance. Although quantifying students' behavioural engagement provides valuable insight on their learning process, future research should consider examining engagement as a multi-dimensional construct and explore the relationship between indicators of behavioural, cognitive, and emotional engagement and how these may influence achievement in a partially flipped learning environment.

The use of an observational session provided insight into why students may have self-identified for a particular approach to learning and how it related to their behavioural engagement and behavioural pattern. However, further research is warranted to observe the trends on a larger scale to be able to draw more meaningful inferences on the effect of these on students' academic performance. Furthermore, it is worth conducting several observational sessions for the same student at various intervals during the semester to examine the extent of variability in their approach and whether the weekly course concepts may be a contributing factor behind why students may keep or alter their learning processes and strategies.

Some research findings were inconclusive. This may in part be attributed to the partially flipped learning model and its online pre-learning materials not being purposefully designed for the studies reported in this thesis and could not be modified by the author. The model was initially implemented as part of a revised curriculum design to improve academic performance, reduce failure rates, and increase class attendance in junior chemistry courses. After three years, this instructional approach was implemented in the intermediate chemistry courses, however, the software used for the pre-learning quizzes differed between the junior and intermediate chemistry courses. Therefore, it was not feasible to access similar data across both junior and intermediate chemistry courses, and data from junior chemistry courses were not collected for students' online behavioural engagement and behavioural pattern. Exploring students' online behavioural engagement and behavioural patterns in junior courses, however, may provide valuable insight regarding students' learning experience in a partially flipped learning model and whether students transferred and adapted their learning strategies into intermediate chemistry courses. Furthermore, it would be interesting to see whether there is a longitudinal effect. It may be possible to identify which learning processes and strategies are transferable or are adjusted from junior to intermediate and senior courses and how these can be used to further maintain or improve engagement levels whilst reflecting learning behaviours that are indicative of a deep approach to learning.

Since the same online pre-learning materials were used across the courses at the same level, the design may not have sufficiently addressed the diversity in student chemistry backgrounds. A different set of online pre-learning materials for each of the different courses might help to improve engagement with the resources as well as impact on displayed behavioural patterns and adopted approaches to learning. Interactive pre-learning videos could be designed with questions varying in difficulty and embedded at intervals to encourage student access to videos whilst simultaneously developing their conceptual and procedural understanding of course material.

In the described model, the quality of the online pre-learning materials embedded were not examined. Although a set of guidelines were given to the instructors, there was no review of the pre-learning materials to determine how they aligned with the guidelines, as well as how similar or different they were across instructors. A review of the materials might assist in teasing out factors that affect students' engagement and learning approaches. Another aspect not examined was the concepts selected for the weekly videos. It might be expected that the concepts which are easier to understand may be associated with less engagement with the pre-learning materials, whilst more rigorous concepts may encourage students to access them more frequently. A possible way that may improve students' engagement with the pre-learning materials is limiting the number of quiz attempts may drive students to viewing the videos first to be better prepared for the quizzes and reduce random repetition. By reviewing the quality and the design of the pre-learning materials it might be possible to identify other factors that influenced the dominant approach to be observed across all three engagement levels and self-identified approach to learning.

Since the theory component across the three intermediate chemistry courses was identical, the same online pre-learning materials. Data were initially aggregated by combining the students across the three intermediate chemistry courses to improve the statistical power of the analysis on a cohort level, and when sample size permitted, data for each course were analysed separately. When data aggregation was necessary, this unfortunately meant that course effect could not be seen, and this is a limitation of the present work and requires additional research to resolve.

The effect of engagement with the pre-learning materials on academic performance is complex. Statistically, a correlation between engagement with the pre-learning materials and course performance was observed. Whether this was due to improved knowledge gained only through the pre-learning materials was not addressed and cannot be easily determined. The results of the limited qualitative research suggest that the pre-learning materials were helpful in providing students with the adequate knowledge needed for the in-class sessions and these could be responsible for the observed improvements in academic performance. It was hoped the partially flipped design would have improved students' motivation to attend and participate in class therefore benefitting them with improved overall course performance. Class attendance and participation, however, were not recorded. Therefore, further research is warranted to examine the direct effect of the online pre-learning materials on students' attendance and engagement during the in-class session.

7.5 Conclusion

It is widely acknowledged that flipped or partially flipped learning models have the potential to revolutionise traditional teaching paradigms. This thesis contributes in several ways to current research on partially flipped learning models in undergraduate chemistry courses. Higher levels of engagement, as measured by an engagement index, led to significant improvements in academic performance. While several behavioural patterns were detected, the dominant behavioural pattern revealed that students tend to favour accessing the quizzes more frequently than the videos. Furthermore, most of the students that self-identified to be strategic learners were mainly categorised to be moderately or highly engaged. In addition, strategic learners preferred to also access the quizzes more frequently than the videos, a dominant behaviour consistently observed throughout the thesis. When comparing students' academic performance, the most pronounced effect was observed in the mainstream courses, suggesting that the online component of the partially flipped learning model greatly benefited students with lower proficiency levels of chemistry. Further recommendations regarding the design of the online pre-learning material were proposed to enhance students' engagement, to encourage the desired behavioural pattern and adopt a deep approach towards learning in a partially flipped learning model.

References

Aben, B., Stapert, S., & Blokland, A. (2012). About the Distinction between Working Memory and Short-Term Memory. *Frontiers in Psychology*, *3*, 301–301.

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

Adams, A. E. M., Garcia, J., & Traustadóttir, T. (2016). A Quasi Experiment to Determine the Effectiveness of a "Partially Flipped" versus "Fully Flipped" Undergraduate Class in Genetics and Evolution. *CBE Life Sciences Education*, *15*(2), 1–9.

Agar, M. H. (1980). *The professional stranger: an informed introduction to ethnography.* San Diego: Academic Press.

AlJarrah, A., Thomas, M. K., & Shehab, M. (2018). Investigating temporal access in a flipped classroom: procrastination persists. *International Journal of Educational Technology in Higher Education*, *15*(1), 1–18.

Allison, P., & Pomeroy, E. (2000). How Shall We "Know?" Epistemological Concerns in Research in Experiential Education. *Journal of Experiential Education*, *23*(2), 91–98.

Al-Samarraie, H., Shamsuddin, A., & Alzahrani, A. I. (2019). A flipped classroom model in higher education: a review of the evidence across disciplines. *Educational Technology Research and Development*, *68*(3), 1017–1051.

Anderson, L. W., & Krathwohl, D. R. (2001). *A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives: Complete Edition*. New York: Longman.

Appleton, J. J., Christenson, S. L., & Furlong, M. J. (2008). Student engagement with school: Critical conceptual and methodological issues of the construct. *Psychology in the Schools*, *45*(5), 369–386.

Armellini, A., Antunes, V. T., & Howe, R. (2021). Student perspectives on learning experiences in a higher education active blended learning context. *TechTrends*, *65*(4), 433–443.

Babbie, E. (2012). *The Practice of Social Research*. Cengage Learning: Florence, KY.

Baeten, M., Kyndt, E., Struyven, K., & Dochy, F. (2010). Using student-centred learning environments to stimulate deep approaches to learning: Factors encouraging or discouraging their effectiveness. *Educational Research Review*, *5*(3), 243–260.

Baggett, P. (1984). Role of temporal overlap of visual and auditory material in forming dual media associations. *Journal of Educational Psychology*, *76*(3), 408–417.

Baker, J. W. (2000, April). The “classroom flip”: Using web course management tools to become the guide by the side. *Paper presented at the 11th international conference on college teaching and learning*, Jacksonville, Florida.

Bancroft, S. F., Jalaeian, M., & John, S. R. (2021). Systematic Review of Flipped Instruction in Undergraduate Chemistry Lectures (2007–2019): Facilitation, Independent Practice, Accountability, and Measure Type Matter. *Journal of Chemical Education*, *98*(7), 2143–2155.

Beatty, B. J., Merchant, Z., & Albert, M. (2019). Analysis of Student Use of Video in a Flipped Classroom. *TechTrends, 63*(4), 376–385.

Bergmann, J., & Sams, A. (2012). *Flip your classroom: reach every student in every class every day* (1st ed.). International Society for Technology in Education.

Biggs, J. B. (1987). *Student approaches to learning and studying*. Melbourne: Australian Council for Educational Research.

Biggs, J. B. (1993). What do inventories of student’s learning processes really measure? A theoretical review and clarification. *British Journal of Educational Psychology, 63*(1), 3–19.

Biggs, J. B. (1999). What the student does: teaching for enhanced learning. *Higher Education Research and Development, 31*(1), 39–55.

Biggs, J., Kember, D., & Leung, D. Y. P. (2001). The revised two-factor Study Process Questionnaire: R-SPQ-2F. *British Journal of Educational Psychology*, *71*(1), 133–149.

Birgili, B., Seggie, F. N., & Oğuz, E. (2021). The trends and outcomes of flipped learning research between 2012 and 2018: A descriptive content analysis. *Journal of Computers in Education (the Official Journal of the Global Chinese Society for Computers in Education)*, *8*(3), 365–394.

Bishop, J. L., & Verleger, M. A. (2013). The Flipped Classroom: A Survey of the Research. *120th American Society for Engineering Education Annual Conference and Exposition*, 30, 1–18.

Bliuc, A.-M., Goodyear, P., & Ellis, R. A. (2007). Research focus and methodological choices in studies into students’ experiences of blended learning in higher education. *The Internet and Higher Education*, *10*(4), 231–244.

Bliuc, A. -M. Ellis, R.A., Goodyear, P., & Piggott, L. (2010). Learning through face-to-face and online discussion: Associations between students’ conceptions, approaches and academic performance in political science. *British Journal of Educational Technology, 41*(3), 512–524.

Bloom, B.S. (1956). *Taxonomy of Educational Objectives, Handbook: The Cognitive Domain*. *xfhen*David McKay, New York.

Bodner, G. M. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education*, *63*(10), 873–878.

Bokosmaty, R., Bridgeman, A., & Muir, M. (2019). Using a Partially Flipped Learning Model To Teach First Year Undergraduate Chemistry. Journal of Chemical Education, 96(4), 629–639.

Bond, M. (2020). Facilitating student engagement through the flipped learning approach in K-12: A systematic review. *Computers and Education, 151,* 103819–.

Bond, M., Buntins, K., Bedenlier, S., Zawacki-Ritchter, O., & Kerres, M. (2020). Mapping research in student engagement and educational technology in higher education: a systematic evidence map. *International Journal of Educational Technology in Higher Education, 17*(2), 1–30.

Bonwell, C. C., & Eison, J. A. (1991). *Active Learning: Creating Excitement in the Classroom. ASHE-ERIC Higher Education Report*. Washington DC: School of Education and Human Development, George Washington University.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.

Bredow, C. A., Roehling, P. V., Knorp, A. J., & Sweet, A. M. (2021). To Flip or Not to Flip? A Meta-Analysis of the Efficacy of Flipped Learning in Higher Education. *Review of Educational Research*, *91*(6), 878–918.

Brennan, A., Sharma, A., & Munguia, P. (2019). Diversity of Online Behaviours Associated with Physical Attendance in Lectures. *Journal of Learning Analytics, 6*(1), 34–53.

Brewer, E. W. (2009). Conducting survey research in education. In C. X. W. Victor (Ed.), *Handbook of research on e-learning applications for career and technical education: Technologies for vocational training* (pp. 519–533). IGI Global

Bridgeman, A. J. YouTube Channel Home Page. https://www.youtube.com/watch?v=vWy3rThoDiU (accessed February 15, 2022).

Bridgeman, A. J. (2011). Collaborative and active eLearning: contributing, ranking and tagging web resources in first year chemistry. In *Proceedings of the Australian conference on Science and Mathematics Education.* Melbourne, Australia, (pp. 54 – 61).

Bridgeman, A. J.; George, A. V. (2014). Personalised learning, support and feedback in a large first year chemistry class, Darwin, Australia. http://fyhe.com.au/past_papers/papers14/07A.pdf. (accessed February 15, 2022).

Bryman, A. (2001). *Social Research Methods*. New York: Oxford University Press.

Bryman, A. (2008). *Social Research Methods*. (3rd ed.). New York: Oxford University Press.

Burgoyne, S., & Eaton, J. (2018). The Partially Flipped Classroom: The Effects of Flipping a Module on "Junk Science" in a Large Methods Course. *Teaching of Psychology, 45*(2), 154–157.

Burke, A. S., & Fedorek, B. (2017). Does "flipping" promote engagement?: A comparison of a traditional, online, and flipped class. *Active Learning in Higher Education*, *18*(1), 11–24.

Burns, R., B. (2000). *Introduction to Research Methods* (4th ed.). French Forest: Pearson Education Australia.

Carlson, M. D. A., & Morrison, R. S. (2009). Study Design, Precision, and Validity in Observational Studies. *Journal of Palliative Medicine, 12*(1), 77–82.

Casasola, T., Nguyen, T., Warschauer, M., & Schenke, K. (2017). Can Flipping the Classroom Work? Evidence from Undergraduate Chemistry. *International Journal of Technology and Learning in Higher Education, 29*(3), 421–435.

Chandler, P. and Sweller, J. (1991). Cognitive Load Theory and the Format of Instruction. *Cognition and Instruction*. *8*(4), 293–332.

Cheng, L., Ritzhaupt, A. D., & Antonenko, P. (2019). Effects of the flipped classroom instructional strategy on students' learning outcomes: a meta-analysis. *Educational Technology Research and Development*, *67*(4), 793–824.

Childers, T., Hvorecký, J., & Majer, O. (2021). Empiricism in the foundations of cognition. *AI & Society*.

Christiansen, M. A. (2014). Inverted Teaching: Applying a New Pedagogy to a University Organic Chemistry Class. *Journal of Chemical Education*, *91*(11), 1845–1850.

Clark, R. C., Nguyen, F., & Sweller, J. (2006). *Efficiency in learning: Evidence-based guidelines to manage cognitive load*. San Francisco: Pfeiffer.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education* (6th ed.). London: Routledge/Farmer.

Cooper, M. M., & Stowe, R. L. (2018). Chemistry Education Research – From Personal Empiricism to Evidence, Theory, and Informed Practice. *Chemical Reviews*, *118*(12), 6053–6087.

Cormier, C. and Voisard, B. (2018). Flipped Classroom in Organic Chemistry Has Significant Effect on Students' Grades. *Frontiers in ICT*, *4*(30).

Cotton, D. R., Stokes, A., & Cotton, P. A. (2010). Using observational methods to research the student experience. *Journal of Geography in Higher Education, 34*(3),463–473.

Cousin, G. (2009). *Researching learning in Higher Education*. London: Routledge.

Cowan, N. (2008). What are the differences between long-term, short- term, and working memory? *Progress in Brain Research,* 169, 323–338.

Creswell, J., W. (2009). *Research Design Qualitative, Quantitative and Mixed Methods Approach*. (3rd ed.). London: Sage Publication.

Crimmins, M. T., & Midkiff, B. (2017). High Structure Active Learning Pedagogy for the Teaching of Organic Chemistry: Assessing the Impact on Academic Outcomes. *Journal of Chemical Education*, *94*(4), 429–438.

Crouch, C. H., & Mazur, E. (2001). Peer Instruction: Ten years of experience and results. *American Journal of Physics*, *69*(9), 970–977.

Danker, B. (2015). Using Flipped Classroom Approach to Explore Deep Learning in Large Classrooms. *IAFOR Journal of Education*, *3*(1), 171–186.

Dazo, S., Stepanek, N., Fulkerson, R., & Dorn, B. (2016). An empirical analysis of video viewing behaviors in flipped CS1 courses. *ACM Inroads*, *7*(4), 99–105.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum.

Deci, E. L., & Ryan, R. M. (1991). A motivational approach to self-integration in personality. In R. Dienstibier (Ed.). *Nebraska Symposium on Motivation Perspective on motivation,* 38, 237–288. Lincoln: University of Nebraska Press.

Deng, R., Benckendorff, P., & Gannaway, D. (2020). Learner engagement in MOOCs : Scale development and validation. *British Journal of Educational Technology*, *51*(1), 245–262.

Denzin, N. K. (1970). Strategies of multiple triangulation. In N. Denzin (ed.) *The Research Act in Sociology: A Theoretical Introduction to Sociological Method*. London: Butterworth, 297–313.

Denzin, N. K., & Lincoln, Y. S. (1994). Introduction: entering the Field of Qualtiative Research. In N. K. Denzin, and Lincoln, Y.S. (Ed.), *Handbook of Qualitative Research* (pp. 1–17). Thousand Oaks: Sage Publications.

Dewey, J. (1916). *Democracy and Education: An introduction to Philosophy of Education*. New York: Macmillian.

Diemer, T. T., Fernandez, E., & Streepey, J. W. (2013). Student perceptions of class engagement learning using iPads. *Journal of Teaching and Learning with Technology, 1*(2), 13–25.

Dooley, L., & Makasis, N. (2020). Understanding Student Behavior in a Flipped Classroom: Interpreting Learning Analytics Data in the Veterinary Pre-Clinical Sciences. *Education Sciences*, *10*, 260, 1–14.

Drost, E. A. (2011). Validity and reliability in social science research. *Education, Research and Perspectives*, *38*(1), 105–123.

Eichler, J. F. (2022). Future of the Flipped Classroom in Chemistry Education: Recognizing the Value of Independent Preclass Learning and Promoting Deeper Understanding of Chemical Ways of Thinking During In-Person Instruction. *Journal of Chemical Education*, *99*(3), 1503–1508.

Eichler, J. F., & Peeples, J. (2016). Flipped classroom modules for large enrolment general chemistry courses: a low barrier approach to increase active learning and improve student grades. *Chemistry Education Research and Practice*, *17*(1), 197–208.

Entwistle, N., & Ramsden, P. (1983). *Understanding student learning*. London: Croom Helm.

Entwistle, N. (2000). Promoting Deep Learning through Teaching and Assessment: Conceptual Frameworks and Educational Contexts. 1st Annual Conference ESRC Teaching and Learning Research Programme (TLRP), University of Leicester, November 2000.

Entwistle, N. J. & Tait, H. (1995). *The Revised Approaches to Studying Inventory*. Edinburgh: University of Edinburgh Centre for Research on Learning and Instruction.

Entwistle, N., & McCune, V. (2004). The Conceptual Bases of Study Strategy Inventories. *Educational Psychology Review*, *16*(4), 325–345.

Fautch, J. (2015). The flipped classroom for teaching organic chemistry in small classes: is it effective? *Chemistry Education Research and Practice,16*(1), 179–186.

Flipped Learning Network (FLN). (2014). The Four Pillars of F-L-I-P™ Reproducible PDF can be found at www.flippedlearning.org/definition.

Floyd, K., Harrington, S. J., & Santiago, J. (2009). The Effect of Engagement and Perceived Course Value on Deep and Surface Learning Strategies. *Informing Science, 12,* 181–190.

Flynn, A. B. (2015). Structure and evaluation of flipped chemistry courses: organic & spectroscopy, large and small, first to third year, English and French. *Chemistry Education Research and Practice, 16*(2), 198–211.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School Engagement: Potential of the Concept, State of the Evidence. *Review of Educational Research*, *74*(1), 59–109.

Fredricks, J. A., & McColskey, W. (2012). The measurement of student engagement: A comparative analysis of various methods and student self-report instruments. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement*, 763–782. Boston, MA: Springer US.

Fredricks, J. A., Filsecker, M., & Lawson, M. A. (2016). Student engagement, context, and adjustment: Addressing definitional, measurement, and methodological issues. *Learning and Instruction, 43,* 1–4.

Gay, L. R., Mills, G.E., & Airasian, P. W. (2009). *Educational research: Competencies for analysis and applications* (9th ed.). Upper Saddle River, New Jersey: Prentice Hall.

Gijbels, D., Segers, M., & Struyf, E. (2008). Constructivist learning environments: Can students' perceptions of assessment demands and their learning strategies be changed in the desired direction? *Instructional Science, 36,* 431–443.

Ginns, P., & Ellis, R. (2007). Quality in blended learning: Exploring the relationships between on-line and face-to-face teaching and learning. *The Internet and Higher Education*, *10*(1), 53–64.

Grix, J. (2002). Introducing Students to the Generic Terminology of Social Research. *Politics, 22*(3), 175–186.

Grix, J. (2004). *The foundations of research*. New York: Palgrave Macmillan.

Hamdan, N., McKnight, P. E., & McKnight, K. (2013). A review of flipped learning. Retrieved from Flipped Learning Network website https://flippedlearning.org/wpcontent/uploads/2016/07/WhitePaper_FlippedLearning.pdf

Hamilton, J., & Tee, S. (2013). Blended teaching and learning: a two-way systems approach. *Higher Education Research and Development*, *32*(5), 748–764.

Hammersley, M. (2014). *Mres programme: Module A core reading: An introduction to social research*. England: The Open University.

Hamm, S., & Robertson, I. (2010). Preferences for deep-surface learning: A vocational education case study using a multimedia assessment activity. *Australasian Journal of Educational Technology, 26*(7), 951–965.

Hava, K. (2021). The effects of the flipped classroom on deep learning strategies and engagement at the undergraduate level. *Participatory Educational Research*, *8*(1), 379–394.

He, W., Holton, A. J., & Farkas, G., & Warschauer, M. (2016). The effects of flipped instruction on out-of-class study time, exam performance and student perceptions. *Learning and Instructions, 45,* 61–67.

He, W., Holton, A. J., & Farkas, G. (2018). Impact of partially flipped instruction on immediate and subsequent course performance in a large undergraduate chemistry course. *Computers and Education*, *125*, 120–131.

Henrie, C. R., Bodily, R., Manwaring, K. C., & Graham, C. R. (2015). Exploring Intensive Longitudinal Measures of Student Engagement in Blended Learning. *International Review of Research in Open and Distance Learning*, *16*(3), 131–155.

Hobson, A. J., & Townsend, A. J. (2010). Interviewing as educational research method(s). In D. Hartas (Ed.), *Educational Research and Inquiry: Qualitative and Quantitative Approaches* (pp. 223–238).

Hsiao, C. C., Huang, J. C. H., Huang, A. Y. Q., Lu, O. H. T., Yin, C. J., & Yang, S. J. H. (2019). Exploring the effects of online learning behaviors on short-term and long term learning outcomes in flipped classrooms. *Interactive Learning Environments*, *27*(8), 1160–1177.

Hu, S., & Kuh, G. D. (2002). Being (Dis)Engaged in Educationally Purposeful Activities:The Influences of Student and Institutional Characteristics. *Research in Higher Education*, *43*(5), 555–575.

Jeong, J. S., González-Gómez, D., Cañada-Cañada, F., Gallego-Picó, A., & Bravo, J. C. (2019). Effects of active learning methodologies on the students' emotions, self efficacy beliefs and learning outcomes in a science distance learning course. *Journal of Technology and Science Education*, *9*(2), 217–227.

Jeong, J. S., González-Gómez, D., Conde-Núñez, M. C., & Gallego-Picó, A. (2019). Examination of students' engagement with R-SPQ-2F of learning approach in flipped sustainable science course. *Journal of Baltic Science Education*, *18*(6), 880–891.

Jesurasa, A., Mackenzie, K., Jordan, H., & Goyder, E. C. (2017). What factors facilitate the engagement with flipped classrooms used in the preparation for postgraduate medical membership examinations? *Advances in Medical Education and Practice*, *8*, 419–426.

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*(2), 75–83.

Johnstone, A. H. (1997). Chemistry Teaching - Science or Alchemy? 1996 Brasted Lecture. *Journal of Chemical Education*, *74*(3), 262–268.

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed method methods research. *Journal of mixed methods research, 1*(2), 112–133.

Johnson, B. & Christensen, L. B. (2012). *Educational Research, Qualitative, Quantitative and Mixed Approach.* (4th ed.). California: Sage Publication.

Joksimović, S., Kovanović, V. & Dawson, S. (2019). The Journey of Learning Analytics. *HERSDA Review of Higher Education,6,* 37–63.

Jovanović, J., Gašević, D., Dawson, S., Pardo, A., & Mirriahi, N. (2017). Learning analytics to unveil learning strategies in a flipped classroom. *The Internet and Higher Education*, *33*, 74–85.

Jovanović, J., Mirriahi, N., Gašević, D., Dawson, S., & Pardo, A. (2019). Predictive power of regularity of pre-class activities in a flipped classroom. *Computers and Education*, *134*, 156–168.

Kahu, E. R. (2013). Framing student engagement in higher education. *Studies in Higher Education (Dorchester-on-Thames)*, *38*(5), 758–773.

Kalyuga, S., Ayres, P., Chandler, P., & Sweller, J. (2003). The expertise reversal effect. *Educational Psychologist, 38*(1), 23–31.

Kayser-Jones, J. and Koenig, B. (1994). `Ethical Issues', in J. F. Gubrium and A. Sankar (eds) *Qualitative Methodology in Aging Research* (pp. 15–32). Thousand Oaks, California: Sage Publications.

Kember, D., & Leung, D. Y. P. (1998). Influences upon Students' Perceptions of Workload. *Educational Psychology (Dorchester-on-Thames)*, *18*(3), 293–307.

Keskin, S., & Yurdugül, H. (2020). Factors Affecting Students' Preferences for Online and Blended Learning: Motivational Vs. Cognitive. *European Journal of Open, Distance and E-Learning*, *22*(2), 72–86.

Kim N. H., So, H.-J., & Joo, Y.J. (2021). Flipped learning design fidelity, self-regulated learning, satisfaction, and continuance intention in a university flipped learning course. *Australasian Journal of Educational Technology*, *37*(4), 1–19.

Kloft, M., Stiehler, F., Zheng, Z., & Pinkwart, N. (2014). Predicting MOOC Dropout over Weeks Using Machine Learning Methods. In *Proceedings of the EMNLP 2014 Workshop on Analysis of Large Scale Social Interaction in MOOCs* (pp. 60–65). Stroudsburg, PA: Association for Computational Linguistics.

Krauss, S. (2015). Research Paradigms and Meaning Making: A Primer. *Qualitative Report,10*(4), 758–770.

Kuhn, T., S. (1970). *The structure of scientific revolutions.* (2nd ed.). Chicago: University of Chicago Press.

Lacher, L. L., & Lewis, M. C. (2014). The value of video quizzes in a computer science flipped classroom: An empirical study. *The 2014 International Conference on Frontiers in Education: Computer Science & Computer Engineering (FECS'14),* 94–100, Las Vegas, USA, July 2014. CSREA.

Lacher, L., & Lewis, M. (2015). The Effectiveness of Video Quizzes in a Flipped Class. *Proceedings of the 46th ACM Technical Symposium on Computer Science Education*, 224–228. ACM.

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.

Lage, M. J., Platt, G. J., & Treglia, M. (2000). Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment. *The Journal of Economic Education*, *31*(1), 30–43.

Lebedev, P., Lindstrøm, C., & Sharma, M. D. (2020). Making linear multimedia interactive: questions, solutions and types of reflection. *European Journal of Physics, 42*(1), 15707–.

Lee, J., Lim, C., & Kim, H. (2017). Development of an instructional design model for flipped learning in higher education. *Educational Technology Research and Development*, *65*(2), 427–453.

Lee, J., Park, T., & Davis, R. O. (2018). What affects learner engagement in flipped learning and what predicts its outcomes? *British Journal of Educational Technology, 53*(2), 211–228.

Lee, J., & Choi, H. (2019). Rethinking the flipped learning pre-class: Its influence on the success of flipped learning and related factors. *British Journal of Educational Technology*, *50*(2), 934–945.

Leiva-Brondo, M., Cebolla-Cornejo, J., Peiró, R., Andrés-Colás, N., Esteras, C., Ferriol, M., & Pérez-de-Castro, A. (2020). Study Approaches of Life Science Students Using the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F). *Education Sciences*, *10*(7), 173.

Leppink, J., Winston, K., & O'Sullivan, P. (2016). Statistical significance does not imply a real effect. *Perspectives on Medical Education, 5*(2), 122–124.

Li, R., Lund, A., & Nordsteien, A. (2021). The link between flipped and active learning: a scoping review. *Teaching in Higher Education,* 1–35.

Linnenbrink-Garcia,L., Rogat, T., & Koskey, K. (2011). Affect and engagement during small group instruction. *Contemporary Educational Psychology, 36*(1)*,* 13–24

Limueco, J., & Prudente, M. (2019). Flipped classroom enhances student's metacognitive awareness. *Proceedings of the 10th international conference on e-Education, e-Business, e-Management and e-Learning,* 70–74.

Long, T., Logan, J., Waugh, M. (2016). Students' perceptions of the value of using videos as a pre-class learning experience in the flipped classroom. *TechTrends,60*(3), 245–252.

Long, T., Zhiyan, W., Yang, X., & Chen, L. (2019). Investigating the Impact of Interactive Pre-Class Learning Videos on Pre-Service Teachers' Learning Performance in Flipped Classroom. *2019 International Symposium on Educational Technology (ISET)*, 155–159.

Ma, J., Han, X., Yang, J., & Cheng, J. (2015). Examining the necessary condition for engagement in an online learning environment based on learning analytics approach: The role of the instructor. *The Internet and Higher Education, 24,* 26–34.

Marton, F., & Saljo, R. (1976). On qualitative differences in learning. I-outcome and process. *British Journal of Educational Psychology, 46*(1)*, 4–11.*

Mayer, R. E. (2005). *The Cambridge Handbook of Multimedia Learning.* New York: Cambridge University Press.

Mayer, R. E., & Moreno, R. (2003). Nine Ways to Reduce Cognitive Load in Multimedia Learning. *Educational Psychologist*, *38*(1), 43–52.

McLean, S., Attardi, S. M., Faden, L., & Goldszmidt, M. (2016). Flipped classrooms and student learning: not just surface gains. *Advances in Physiology Education*, *40*(1), 47–55.

Meijer, P. C., Verloop, N., Beijaard, D. (2002). Multi-method triangulation in a qualitative study on teachers' practical knowledge: An attempt to increase internal validity. *Quality & Quantity, 36*(2), 145–167.

Merrill, M. D. (2013). *First principles of instruction: Identifying and designing effective, efficient, and engaging instruction.* San Francisco, CA: Pfeiffer.

Meyliana, Sablan, B., Surjandy, & Hidayanto, A. N. (2022). Flipped learning effect on classroom engagement and outcomes in university information systems class. *Education and Information Technologies*, *27*(3), 3341–3359.

Miller, G. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *The psychological review*, *63*(2), 81–97.

Minichiello, V. (2004). *In-Depth Interviewing: Principles, Techniques, Analysis.* (3rd ed.). Pearson Australia Group: Longman.

Mishra, P., Pandey, C. M., Singh, U., Keshri, A., & Sabaretnam, M. (2019). Selection of appropriate statistical methods for data analysis. *Annals of cardiac anaesthesia*, *22*(3), 297–301.

Moog, R. S. & Spencer, J. N. (2008). *POGIL: Process Orientated Guided Inquiry Learning.* Oxford University Press, New York.

Mooring, S. R., Mitchell, C. E., & Burrows, N. L. (2016). Evaluation of a Flipped, Large Enrollment Organic Chemistry Course on Student Attitude and Achievement. *Journal of Chemical Education*, *93*(12), 1972–1983.

Mori, T. (2017). The Flipped Classroom: An Instructional Framework for Promotion of Active Learning. *Deep Active Learning*. Singapore: Springer Singapore, 95–109.

Naibert, N., Geye, E., Phillips, M. M., & Barbera, J. (2020). Multicourse Comparative Study of the Core Aspects for Flipped Learning: Investigating In-Class Structure and Student Use of Video Resources. *Journal of Chemical Education*, *97*(10), 3490–3505.

National Educational Standards Authority (2018). *Subject content knowledge requirements (abridged)*. https://educationstandards.nsw.edu.au/wps/wcm/connect/ae7db0fc-4a6d 4904-b635-f70147e0dc3c/subject-content-knowledge requirementsrecent.pdf?MOD=AJPERES&CVID=

National Health and Medical Research Council, Australian Research Council and Australian Vice Chancellor's Committee. (2007). *National Statement on Ethical Conduct in Human Research.* Canberra, ACT: Australian Government Printing Service.

Neimeyer, G. J., & Morton, R. J. (1997). Personal epistemologies and preferences for rationalist versus constructivist psychotherapies. *Journal of Constructivist Psychology*, *10*(2), 109–123.

Nijhuis, J. F. H., Segers, M. S. R., & Gijselaers, W. H. (2005). Influence of Redesigning a Learning Environment on Student Perceptions and Learning Strategies. *Learning Environments Research, 8*(1), 67–93.

Nijhuis, J. F. H., Segers, M. S. R., & Gijselaers, W. H. (2008). The extent of variability in learning strategies and students' perceptions of the learning environment. *Learning and Instruction, 18*(2), 121–134.

Nilson, L.B. (2010). Teaching at its Best: A Research-based Resource for College Instructors. John Wiley & Sons, San Francisco, CA.

Ntoumanis, N. (2001). A self-determination approach to the understanding of motivation in physical education. *British Journal of Educational Psychology, 71*(2), 225–242.

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.

Parab, S., & Bhalerao, S. (2010). Choosing statistical test. *International journal of Ayurveda research*, *1*(3), 187–191.

Piaget, J. (1952). *The Origins of Intelligence in Children.* New York: International University Press.

Ponikwer, F., & Patel, B. A. (2018). Implementation and evaluation of flipped learning for delivery of analytical chemistry topics. *Analytical and Bioanalytical Chemistry*, *410*(9), 2263–2269.

Powney, J., & Watts, M. (1987). *Interviewing in Educational Research.* London: Routledge and Kegan Paul.

Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education. 93*(3), 223–231.

Rahman, T., & Lewis, S. E. (2020). Evaluating the evidence base for evidence-based instructional practices in chemistry through meta-analysis. *Journal of Research in Science Teaching*, *57*(5), 765–793.

Ramsden, P. (1979). Student learning and perceptions of the academic environment. *Higher Education, 8*(4), 411–427.

Ramsden, P. (2003). *Learning to teach in higher education.* (2nd ed.). London & New York: Routledge Falmer.

Ratner, B. (2009). The correlation coefficient: Its values range between +1/−1, or do they? *Journal of Targeting, Measurement and Analysis Marketing*, *17*(2), 139–142.

Reeve, J., & Tseng, C. M. (2011). Agency as a fourth aspect of students' engagement during learning activities. *Contemporary Educational Psychology, 36*(4)*,* 257–267

Richardson, M., Abraham, C., & Bond, R. (2012). Psychological Correlates of University Students Academic Performance: A Systematic Review and Meta-Analysis. *Psychological Bulletin, 138*(2), 353–387.

Roach. T. (2014). Student perceptions toward flipped learning: New methods to increase interaction and active learning in economics. *International Review of Economics Education*, *17*, 74–84.

Ryan, M. D., & Reid, S. A. (2016). Impact of the Flipped Classroom on Student Performance and Retention: A Parallel Controlled Study in General Chemistry. *Journal of Chemical Education, 93*(1), 13–23.

Saldaña, J. (2012). *The coding manual for qualitative reserachers* (2nd ed.). Sage Publications.

Schunk, D. H. (1996). *Learning Theories: An Educational Perspective* (2nd ed.). Englewood Cliffs, NJ: Merrill.

Seery, M. (2015). Flipped learning in higher education chemistry: Emerging trends and potential directions. *Chemistry Education Research and Practice, 16*(4)*,* 758–768.

Seery, M. K., & Donnelly, R. (2012). The implementation of pre-lecture resources to reduce in-class cognitive load: A case study for higher education chemistry. *British Journal of Educational Technology*, *43*(4), 667–677.

Shattuck, J. C. (2016). A Parallel Controlled Study of the Effectiveness of a Partially Flipped Organic Chemistry Course on Student Performance, Perceptions, and Course Completion. *Journal of Chemical Education*, *93*(12), 1984–1992.

Sigurðardóttir, M. S., & Heijstra, T. M. (2020). Mixed Approaches to Learning in the Flipped Classroom: How Students Approach the Learning Environment. *The Canadian Journal for the Scholarship of Teaching and Learning, 11*(1), 1–15.

Smallhorn, M. (2017). The flipped classroom: A learning model to increase student engagement not academic achievement. *Student Success*, *8*(2), 43–53.

Smith, J. D. (2013). Student attitudes toward flipping the general chemistry classroom. *Chemistry Education Research. Practice. 14*(4), 607–614.

Smith, J. K. (1983). Quantitative Versus Qualitative Research: An Attempt to Clarify the Issue. *Educational Researcher*, *12*(3), 6–13.

Socha, A., & Sigler, E. A. (2014). Exploring and “reconciling” the factor structure for the Revised Two-factor Study Process Questionnaire. *Learning and Individual Differences, 31,* 43–50.

Subramaniam, S. R., & Muniandy, B. (2019). The Effect of Flipped Classroom on Students’ Engagement. *Technology, Knowledge and Learning*, *24*(3), 355–372.

Sullivan, G. M., & Feinn, R. (2012). Using Effect Size-or Why the P Value Is Not Enough. *Journal of graduate medical education*, *4*(3), 279–282.

Swan, K. (2004). Learning online: current research on issues of interface, teaching presence and learner characteristics. In J. Bourne & J. C. Moore (Eds).*Elements of Quality Online Education, Into the Mainstream.* Needham, MA: Sloan Center for Online Education, 63–79.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, *12*(2), 257–285.

Sweller, J., van Merrienboer, J.J. G., & Paas, F.G.W. (1998). Cognitive Architecture and Instructional Design. *Educational Psychology Review*, *10*(3), 251– 296.

Sydney 2nd year chem. (2022, June 15). *Chem2 pre-lecture videos.* [video] *https://www.youtube.com/playlist?list=PLpktFoehhDrV7xVnIyz-ShgH4mAATPZhW*

Tait, H., Entwistle, N. J., & McCune, V. (1998). *ASSIST: a reconceptualization of the Approaches to Studying Inventory.* In C.Rust (ed.) *Improving students as learners.* Oxford: Oxford Brookes University, The Oxford Centre for Staff and Learning Development.

Tasker, R., Miller, J., Kemmett, C. and Bedgood Jnr, D.R. (2003). *Analysis of Student Engagement with Online Chemistry Modules Using Tracking Data.* Paper presented at the Interact, Integrate, Impact: Proceedings of the 20th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education, Adelaide.

The University of Sydney. (2017). Privacy Policy of the University of Sydney. From https://www.sydney.edu.au/policies/showdoc.aspx?recnum=PDOC2011/81&RendNum=0

The University of Sydney. (2021). The University of Sydney, School of Chemistry, Unit outline from https://www.sydney.edu.au/units

Thomas, J. (2009). *The Minds of the Moderns: Rationalism, Empiricism and Philosophy of Mind* (1st ed.). Routledge.

Tomlinson, P. (1989). Having it Both Ways: hierarchical focusing as research interview method. *British Educational Research Journal*, *15*(2), 155–176.

Trilling, B., & Fadel, C. (2009). *21st Century Skills: Learning for Life in Our Times*. San Francisco, CA: John Wiley & Sons.

Velázquez-Marcano, A., Williamson, V. M., Ashkenazi, G., Tasker, R., & Williamson, K. C. (2004). The Use of Video Demonstrations and Particulate Animation in General Chemistry. *Journal of Science Education and Technology*, *13*(3), 315–323.

Venkatesh, V., Brown, S. A., & Bala, H. (2013). Bridging the Qualitative-Quantitative Divide: Guidelines for Conducting Mixed Methods Research in Information Systems. *MIS Quarterly*, *37*(1), 21–54.

Vidic, N., Clark, R. M., & Claypool E. G. (2015). Flipped Classroom Approach: Probability and Statistics Course for Engineers. *Association for Engineering Education–Engineering Library Division Papers, 26.782.*1–14.

Vidic, N., & Clark, R. M. (2016). Comparison of a Partially Flipped vs. Fully Flipped Introductory Probability and Statistics Course for Engineers: Lessons Learned. *Association for Engineering Education - Engineering Library Division Papers*. Atlanta: American Society for Engineering Education-ASEE.

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes.* Cambridge: Harvard University Press.

Wang, F. H. (2017). An exploration of online behavioral engagement and achievement in flipped classroom supported by learning management system. *Computers and Education, 114*, 79–91.

Wang, M. T., & Fredricks, J. A. (2014). The reciprocal links between school engagement and youth problem behavior during adolescence. *Child Development, 85*(2), 722–737.

Wang, F. H. (2019). On the relationships between behaviors and achievement in technology mediated flipped classrooms: A two-phase online behavioural PLS-SEM model. *Computers and Education, 142*, 103653.

Ward, J.H. (1963). Hierarchical Grouping to Optimize an Objective Function. *Journal of the American Statistical Association, 58*(301), 236–244.

Weaver, G. C., & Sturtevant, H. G. (2015). Design, Implementation, and Evaluation of a Flipped Format General Chemistry Course. *Journal of Chemical Education*, *92*(9), 1437–1448.

Williams, M. (1996). Understanding Human Knowledge Philosophically. *Philosophy and Phenomenological Research*, *56*(2), 359–378.

Xiu, Y., Moore, M. E., Thompson, P., & French, D. P. (2019). Student Perceptions of Lecture-Capture Video to Facilitate Learning in a Flipped Classroom. *TechTrends*, *63*(4), 369–375.

Yestrebsky, C. L. (2015). Flipping the Classroom in a Large Chemistry Class-research University Environment. *Procedia, Social and Behavioral Sciences*, *191*, 1113–1118.

Yuan, L., & Powell, S. (2013). *MOOCs and Open Education: Implications for Higher Education*. Glasgow: JISC CETIS.

Zeegers, P. (2001). Student learning in science: a longitudinal study. *British Journal of Educational Psychology, 71*(1)*,* 115–132.

Zhao, L., He, W., & Su, Y.-S. (2021). Innovative Pedagogy and Design-Based Research on Flipped Learning in Higher Education. *Frontiers in Psychology*, *12*, 577002–577002.

Zimmerman, D. W. (2004). A note on preliminary tests of equality of variance. In: *British Journal of Mathematical and Statistical Psychology, 51*(1), (pp. 173–181).

Appendix A: Ethics approval letter

Project 2014/219

Research Integrity
Human Research Ethics Committee

Wednesday, 23 April 2014

Dr Louise Sutherland
School Development & Learning; Faculty of Education & Social Work
Email: louise.sutherland@sydney.edu.au

Dear Louise

I am pleased to inform you that the Humanities Low Risk Subcommittee has approved your project entitled "**A Flipped classroom approach to teaching the Fundamentals of Chemistry: The students' online learning experience**".

Details of the approval are as follows:

Project No.: **2014/219**

Approval Date: **23 April 2014**

First Annual Report Due: **23 April 2015**

Authorised Personnel: **Sutherland Louise; Bokosmaty Rena; Bridgeman Adam;**

Documents Approved:

Date Uploaded	**Type**	**Document Name**
11/04/2014	Advertisements/Flyer	Consent Form
11/04/2014	Advertisements/Flyer	Participant Information Statement
11/04/2014	Advertisements/Flyer	Part 1: Questionnaire
11/04/2014	Advertisements/Flyer	Part 2: Observation and Semi-structured interview

HREC approval is valid for four (4) years from the approval date stated in this letter and is granted pending the following conditions being met:

Condition/s of Approval

- Continuing compliance with the National Statement on Ethical Conduct in Research Involving Humans.
- Provision of an annual report on this research to the Human Research Ethics Committee from the approval date and at the completion of the study. Failure to submit reports will result in withdrawal of ethics approval for the project.
- All serious and unexpected adverse events should be reported to the HREC within 72 hours.
- All unforeseen events that might affect continued ethical acceptability of the project should be reported to the HREC as soon as possible.
- Any changes to the project including changes to research personnel must be approved by the HREC before the research project can proceed.

Research Integrity
Research Portfolio
Level 6, Jane Foss Russell
The University of Sydney
NSW 2006 Australia

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sydney.edu.au

ABN 15 211 513 464
CRICOS 00026A

- Note that for student research projects, a copy of this letter must be included in the candidate's thesis.

Chief Investigator / Supervisor's responsibilities:

1. You must retain copies of all signed Consent Forms (if applicable) and provide these to the HREC on request.

2. It is your responsibility to provide a copy of this letter to any internal/external granting agencies if requested.

Please do not hesitate to contact Research Integrity (Human Ethics) should you require further information or clarification.

Yours sincerely

J a Cashmore

Associate Professor Judith Cashmore
Chair
Humanities Low Risk Subcommittee

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) National Statement on Ethical Conduct in Human Research (2007), NHMRC and Universities Australia Australian Code for the Responsible Conduct of Research (2007) and the CPMP/ICH Note for Guidance on Good Clinical Practice.

Project 2016/190

From:	Human Ethics
To:	Siegbert Schmid; "ajon7216@uni.sydney.edu.au"; Adam Bridgeman
Subject:	2016/190 - HREC application outcome
Date:	Wednesday, 16 March 2016 4:25:00 PM

Dear Assoc Prof Siegbert Schmid,

Project Title: Investigating the Efficacy of Flipped Learning to Promote Student Engagement and Achievement
Project No: 2016/190

Your ethics application was considered at the Humanities Review Committee meeting held on the 7th of March 2016.

The Committee approved this application in principle, subject to the following additional information being sought and reviewed by the Ethics Office. The application received a **Category B Office**.

From:	Human Ethics
To:	Siegbert Schmid; Adam Bridgeman; Ayla Jones (ajon7216@uni.sydney.edu.au); "rbok9807@uni.sydney.edu.au"
Subject:	[2016/190] Human Ethics: Change in personnel outcome
Date:	Tuesday, 27 September 2016 1:01:00 PM

Dear Assoc Prof Schmid

Project Title: Investigating the Efficacy of Flipped Learning to Promote Student Engagement and Achievement
Project number: 2016/190

Change in Personnel outcome

Thank you for submitting a change in personnel form for the above project. Your request has been processed and the change/s approved.

The current approved researchers are as follows:

Schmid Siegbert; Bridgeman Adam; Jones Ayla; Bokosmaty Rena;

Please contact us if you have any queries or if there is an error in the above list.

Regards,
The Ethics Office

Research Integrity & Ethics Administration | Research Portfolio
THE UNIVERSITY OF SYDNEY
Level 2 Margaret Telfer Building (K07) | The University of Sydney | NSW | 2006
T +61 2 9036 9161 | **E** human.ethics@sydney.edu.au | **W** http://sydney.edu.au/ethics

Appendix B: Project 2014/219

THE UNIVERSITY OF SYDNEY

Faculty of Science – School of Chemistry

Professor Adam Bridgeman

Associate Dean (Learning and Teaching)
Director of First Year Studies (Chemistry)

Room 543A
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Telephone: +61 2 9351 2731
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Web: http://www.sydney.edu.au/

A flipped classroom approach to teaching Chemistry: The students' online learning experience

PARTICIPANT INFORMATION STATEMENT

(1) What is the study about?

You are invited to participate in a study that examines first year chemistry students' online learning experience in a flipped classroom. The study aims to understand *how* chemistry students approach the online learning activities in the second year chemistry units. The study seeks to analyse *what* students do whilst completing the online activities and *what* they think they are learning in the online component of the unit.

(2) Who is carrying out the study?

The study is being conducted by Rena Bokosmaty (student) and will form the basis for the degree of Doctor of Philosophy at The University of Sydney under the supervision of Associate Professor Adam Bridgeman and Dr. Meloni Muir.

(3) What does the study involve?

There are **two parts** to this study. *For Part 1,* If you decide to participate in this part of the study, you will be asked to complete a 20 minute questionnaire which will seek to establish an understanding about your learning experience of the online activities in the unit. Participants may remain anonymous by providing no personal details or contact information. You can indicate your consent to participating in this component of the study by returning the completed questionnaire.

However, if you are willing to participate in the second part of this study, please provide your contact information at the end of the questionnaire.

In Part 2, there are two components. Firstly, a video observation of your activities whilst completing the online activities assigned to you that week. Secondly, a short follow-up interview will be conducted to clarify the researchers' observation and your reaction to the online learning experience in the chemistry unit. This interview should take approximately 30 minutes. With your permission, the interview will be audio and video recorded.

(4) How much time will the study take?

Part 1: The questionnaire will be completed in 20 minutes. Part 2: The observation and the interview should take approximately 30minutes.

(5) Can I withdraw from the study?

Being in this study is completely voluntary - you are not under any obligation to consent and - if you do consent - you can withdraw at any time without affecting your relationship with The University of Sydney.
You may stop the interview at any time if you do not wish to continue, the audio recording and video will be erased and the information provided will not be included in the study.
Being in this study is completely voluntary and you are not under any obligation to consent to complete the questionnaire/survey. Submitting a completed questionnaire/survey is an indication of your consent to participate in the study. You can withdraw any time prior to submitting your completed questionnaire/survey. Once you have submitted your questionnaire/survey anonymously, your responses cannot be withdrawn.

(6) Will anyone else know the results?

All aspects of the study, including results, will be strictly confidential and only the researchers will have access to information on participants.

A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report.

(7) Will the study benefit me?

This study offers the potential of benefiting future students learning chemistry at the University of Sydney; however, we cannot and do not guarantee or promise that you will receive any benefits from the study.

(8) Can I tell other people about the study?

You are free to discuss this study with other people.

(9) What if I require further information about the study or my involvement in it?

When you have read this information, Rena Bokosmaty will discuss it with you further and answer any questions you may have. If you would like to know more at any stage, please feel free to contact Rena Bokosmaty on 0452 135 351 or email: rbok9807@uni.sydney.edu.au, or Associate Professor Adam Bridgeman on 02 *9351 2731 or email:* adam.bridgeman@sydney.edu.au

(10) What if I have a complaint or any concerns?

Any person with concerns or complaints about the conduct of a research study can contact The Manager, Human Ethics Administration, University of Sydney on +61 2 8627 8176 (Telephone); +61 2 8627 8177 (Facsimile) or ro.humanethics@sydney.edu.au (Email).Project 2

Appendix C: Project 2016/190

School of Chemistry
Faculty of Science

THE UNIVERSITY OF SYDNEY

ABN 15 211 513 464

Associate Professor Siegbert Schmid
Second Year Director (Chemistry)

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Chemistry Building F11
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NSW 2006 AUSTRALIA
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Web: http://www.sydney.edu.au/

Investigating the Efficacy of Flipped Learning to Promote Student Engagement and Achievement

PARTICIPANT INFORMATION STATEMENT

(1) What is this study about?

You are invited to take part in a research study about the use of flipped learning, including pre-class videos and in-class activities in Second Year Chemistry.

You have been invited to participate in this study because you are enrolled in CHEM2401/2911/2915 and/or CHEM2402/2912/2916. This Participant Information Statement tells you about the research study. Knowing what is involved will help you decide if you want to take part in the research. Please read this sheet carefully and ask questions about anything that you do not understand or want to know more about.

Participation in this research study is voluntary.

By giving your consent to take part in this study you are telling us that you:

- ✓ Understand what you have read.
- ✓ Agree to take part in the research study as outlined below.
- ✓ Agree to the use of your personal information as described.

You will be given a copy of this Participant Information Statement to keep.

(2) Who is running the study?

Ayla Jones is conducting this study as the basis for the degree of Bachelor of Science (Honours) at The University of Sydney. This will take place under the supervision of Associate Professor Siegbert Schmid and Professor Adam Bridgeman.

(3) What will the study involve for me?

You will be asked to complete a short survey in hard copy about your expectations for Second Year Chemistry at the beginning of Semester One, 2016. This will be distributed in labs. You may also be asked to complete a second survey about your learning experience at the end of

Semester, distributed in tutorials. If you are interested, you may participate in an interview about your Second Year Chemistry experience.
In order to investigate the effectiveness of online learning activities we want to link your performance results, including quizzes and the final exam, with your survey responses. These results will be accessed by the Honours student through eLearning/Blackboard.

(4) How much of my time will the study take?

The first survey will take about 5 minutes to complete. The second survey will also take about 5 minutes. The interview will take about 15-20 minutes. If you complete all parts of the study, the total amount of time could be up to 30 minutes.

(5) Who can take part in the study?

Any Second Year Chemistry Student enrolled in CHEM2401/2911/2915 and/or CHEM2402/2912/2916 can take part in the study.

(6) Do I have to be in the study? Can I withdraw from the study once I have started?

Being in this study is completely voluntary and you do not have to take part. Your decision whether to participate will not affect your current or future relationship with the researchers or anyone else at the University of Sydney.

Submitting your completed questionnaire is an indication of your consent to participate in the study. You can withdraw your responses if you change your mind about having them included in the study, up to the point when the SID, if you provided it, has been removed.

If you choose to participate in the interview, you are free to stop the interview at any time. Unless you say that you want us to keep them, any recordings will be erased and the information you have provided will not be included in the study results. You may also refuse to answer any questions that you do not wish to answer during the interview.

If you decide to take part in the study and then change your mind later, you are free to withdraw at any time. You can do this by contacting the Honours student on the project, Ayla Jones, at ajon7216@uni.sydney.edu.au.

If you decide to withdraw from the study, we will not collect any more information from you. Please let us know at the time when you withdraw what you would like us to do with the information we have collected about you up to that point. If you wish your information will be removed from our study records and will not be included in the study results, up to the point when the SID, if you provided it, has been removed.

(7) Are there any risks or costs associated with being in the study?

Aside from giving up your time, we do not expect that there will be any risks or costs associated with taking part in this study.

(8) Are there any benefits associated with being in the study?

This study offers the potential of benefitting future students learning chemistry at the University of Sydney. We cannot guarantee that you will receive any direct benefits from being in the study.

(9) What will happen to information about me that is collected during the study?

By providing your consent, you are agreeing to us collecting personal information about you for the purposes of this research study. Your information will only be used for the purposes outlined in this Participant Information Statement. This information may include survey responses, assessment results, elearning records and interview recordings.
Your information will be stored securely on hard drives accessible only to the researchers and your identity/information will be kept strictly confidential, except as required by law. Hard copy files will be securely stored in the Chemistry Building, room 315. Study findings may be published, but you will not be individually identifiable in these publications. Data will be retained for 5 years following the study, and will then be destroyed.
The findings from the study will be published in an Honours thesis, and may also be published in journals and/or conference presentations.

(10) Can I tell other people about the study?

Yes, you are welcome to tell other people about the study.

(11) What if I would like further information about the study?

When you have read this information, Ayla Jones will be available to discuss it with you further and answer any questions you may have. If you would like to know more at any stage during the study, please feel free to contact Ayla Jones at ajon7216@uni.sydney.edu.au or 0478 137 617.

(12) Will I be told the results of the study?

You have a right to receive feedback about the overall results of this study. We will be emailing all Second Year Chemistry students enrolled in CHEM2401/2911/2915 and/or CHEM2402/2912/2916 a one page summary of the results. You will receive this feedback after the study is finished.

(13) What if I have a complaint or any concerns about the study?

Research involving humans in Australia is reviewed by an independent group of people called a Human Research Ethics Committee (HREC). The ethical aspects of this study have been approved by the HREC of the University of Sydney *[INSERT* protocol number once approval is obtained*].* As part of this process, we have agreed to carry out the study according to the *National Statement on Ethical Conduct in Human Research (2007).* This statement has been developed to protect people who agree to take part in research studies.

If you are concerned about the way this study is being conducted or you wish to make a complaint to someone independent from the study, please contact the university using the details outlined below. Please quote the study title and protocol number.

The Manager, Ethics Administration, University of Sydney:

- **Telephone:** +61 2 8627 8176
- **Email:** ro.humanethics@sydney.edu.au
- **Fax:** +61 2 8627 8177 (Facsimile)

Appendix D: The R-SPQ-2F questionnaire

ABN 15 211 513 464

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Director of First Year Studies (Chemistry)

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Web: http://www.sydney.edu.au/

A flipped classroom approach to teaching Chemistry: The students' online learning experience

PARTICIPANT QUESTIONNAIRE

Dear Participants,

Thank you for participating in this study that examines first year chemistry students' learning experience in the online component of the flipped classroom.

Please make sure you have read the **Participant Information Statement** before answering this questionnaire. You will be asked to circle the number that best corresponds to your level of response to each item. When answering the questionnaire, if you want to change an answer just cross it out and circle the answer you prefer.

This questionnaire is anonymous, and your answers will only be seen by the researchers.

Submission of the survey implies your consent to participating in this study. Once the survey has been submitted it will not be possible to withdraw your responses.

Part A – Background Information

1. What degree are you currently enrolled in?_____________________________
2. **Circle** the appropriate answer that supports your main reasons for enrolling in the fundamental chemistry unit (CHEM1001):
    a. Have no background in chemistry
    b. Had to do chemistry as it was a pre-requisite for a second year subject
    c. Doing chemistry for interest
    d. Other(please provide a brief reason below)
    ____
    ____
    ____

Any person with concerns or complaints about the conduct of a research study can contact The Manager, Human Ethics Administration, University of Sydney on +61 2 8627 8176 (Telephone); +61 2 8627 8177 (Facsimile) or ro.humanethics@sydney.edu.au (Email).

Part B

Please select the letter that best describes **your approach towards learning** chemistry:

A Strongly agree **B** Agree **C** Neutral **D** Disagree **E** Strongly disagree

Questionnaire retrieved from: Biggs, J.B., Kember, D., & Leung, D.Y.P. (2001). The revised two factor study process questionnaire: R-SPQ 2F.*British*

	SA	A	N	D	SD
1. I find that at times studying gives me a feeling of deep personal satisfaction	A	B	C	D	E
2. I find that I have to do enough work on a topic so that I can form my own conclusion before I am satisfied	A	B	C	D	E
3. My aim is to pass the course while doing as little work as possible	A	B	C	D	E
4. I only study seriously what's given out in class or in the course outline	A	B	C	D	E
5. I feel that virtually any topic can be highlight interesting once I get into it	A	B	C	D	E
6. I find most new topics interesting and often spend extra time trying to obtain more information about them	A	B	C	D	E
7. I do not find my course very interesting so I keep my work to the minimum	A	B	C	D	E
8. I learn some things by rote, going over and over them until I know them by heart even if I do not understand them	A	B	C	D	E
9. I find that studying academic topics can at times be as exciting as a good novel or movie	A	B	C	D	E
10. I test myself on important topics until I understand them completely	A	B	C	D	E
11. I find I can get by in most assessments by memorising key sections rather than trying to understand them	A	B	C	D	E
12. I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra	A	B	C	D	E
13. I work hard at my studies because I find the material interesting	A	B	C	D	E
14. I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes	A	B	C	D	E
15. I find it is not helpful to study topics in depth. It confuses and wastes time when all you need is a passing acquaintance with topics	A	B	C	D	E
16. I believe that lecturers shouldn't expect students to spend significant amounts of time studying material everyone knows won't be examined	A	B	C	D	E
17. I came to most classes with questions in mind that I want answering	A	B	C	D	E
18. I make a point of looking at most of the suggested readings that go with the lectures	A	B	C	D	E
19. I see no point in learning material which is not likely to be in the examination	A	B	C	D	E
20. I find the best way to pass examinations is to try to remember answers to likely questions	A	B	C	D	E

Journal of Educational psychology. 71, 133-14

Appendix E: Students' perception towards the online pre-learning materials questionnaire

Part C: Video tutorials

1. Do you watch the online video tutorials?
    a. Yes (Go to question 3)
    b. No

Please select the letters that best describes your approach towards learning chemistry (circle more than one answer)

2. Why do you not watch the online video tutorials?
    a. I did not know the videos existed.
    b. I do not need the videos to do the quizzes.
    c. The videos are not helpful to my learning.
    d. I do not have time to watch the videos.
    e. The videos are too long.
    f. Other, please explain briefly

3. Why do you watch the online video tutorials?
    a. Watching the videos helps me do better on the quizzes.
    b. The videos are helpful to my learning.
    c. Other, please explain briefly

Please select the letter that best describes your approach towards learning chemistry

4. The online video tutorials are helpful for introducing new concepts.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree
5. The online video tutorials aid my understanding of the chemical concepts covered each week.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

6. The online video tutorials give me background knowledge for content discussed during class time.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

Part D: Online quizzes

1. Do you complete the online quizzes?
    a. Yes (go to question 3)
    b. No

Please select the letters that best describes your approach towards learning chemistry (circle more than one answer)

2. Why do you not complete the online quizzes?
    a. I do not have time
    b. The quizzes are not helpful for learning
    c. The contribution of the quizzes to my final mark is too small to bother doing the quizzes.
    d. Other, please explain briefly ____

3. I complete the online quizzes because
    a. The quizzes contribute to my mark
    b. The quizzes are easy marks
    c. The quizzes help me understand concepts
    d. The quizzes are good revision tool
    e. Other, please explain briefly ____

Please select the letter that best describes your approach towards learning chemistry

4. The online quizzes enhance my learning experience.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

5. The link between the online quizzes and the pre-lecture videos is clear.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree

Part E: Feedback on video tutorials and online quizzes?

1. What aspects do you find most helpful in the video tutorials?

2. What aspects do you find most helpful in the online quizzes?

3. What improvements to the video tutorials and online quizzes would you recommend to improve your learning in this unit?

If you are willing to participate in a follow up observation and interview to discuss your experience towards the online learning activities please provide further details bellow:

Name: **SID (optional):**

Contact email: **Contact number:**

END OF QUESTIONNAIRE- Thank you for your participation

Appendix F: Comparison of performance between pre-learning quiz and other course assessment for Group B1

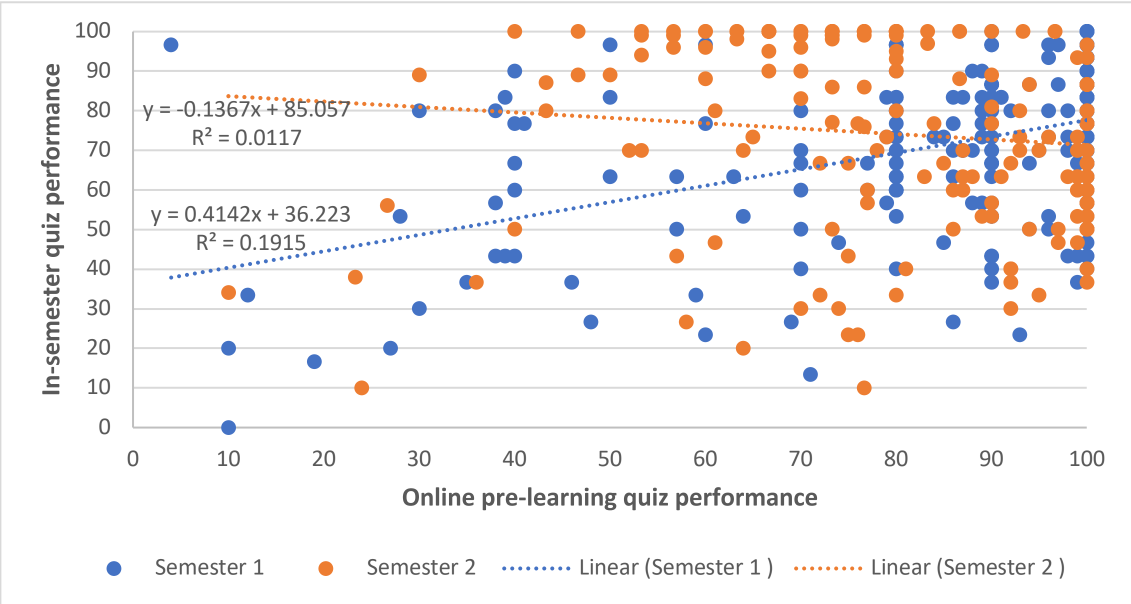

Figure F.1. Comparison of performance between pre-learning quiz and in-semester quiz.

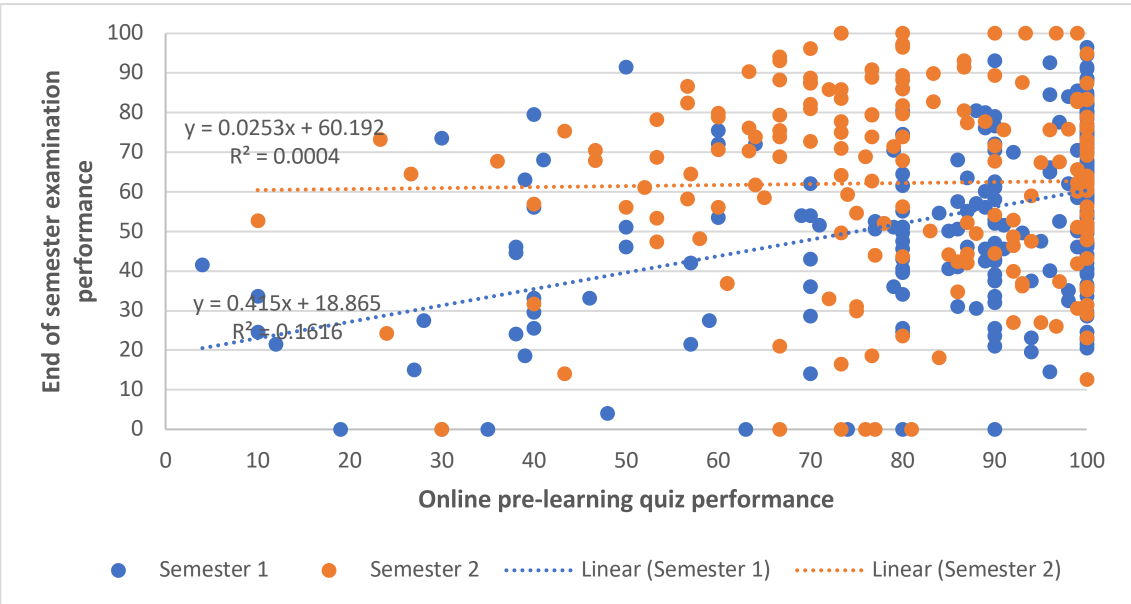

Figure F.2. Comparison of performance between pre-learning quiz and end of semester examination.

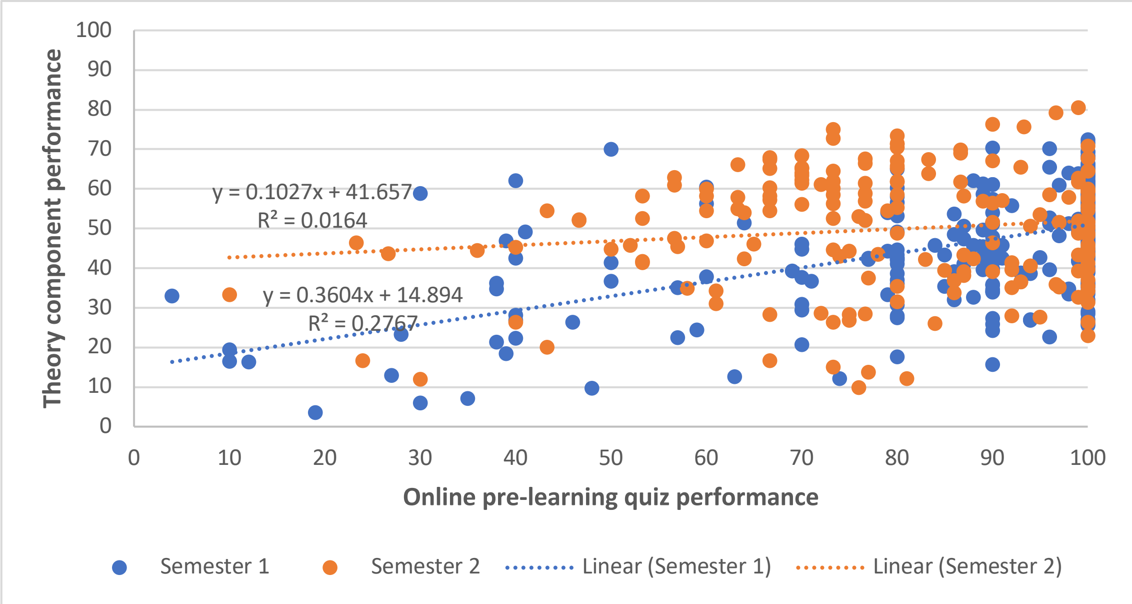

Figure F.3. Comparison of performance between pre-learning quiz and theory component.

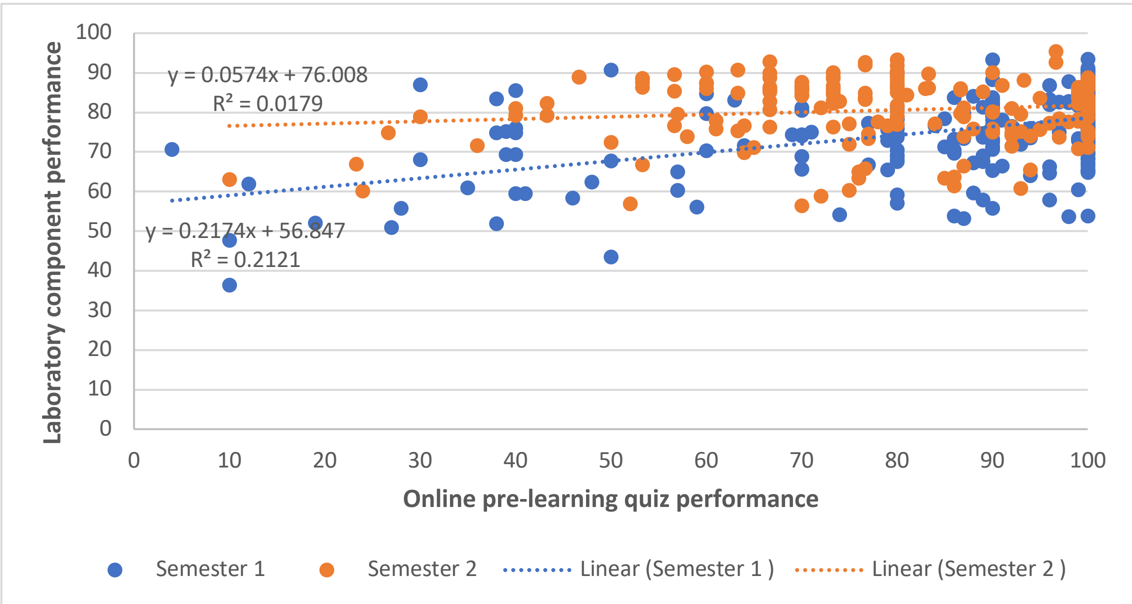

Figure F.4. Comparison of performance between pre-learning quiz and laboratory component.

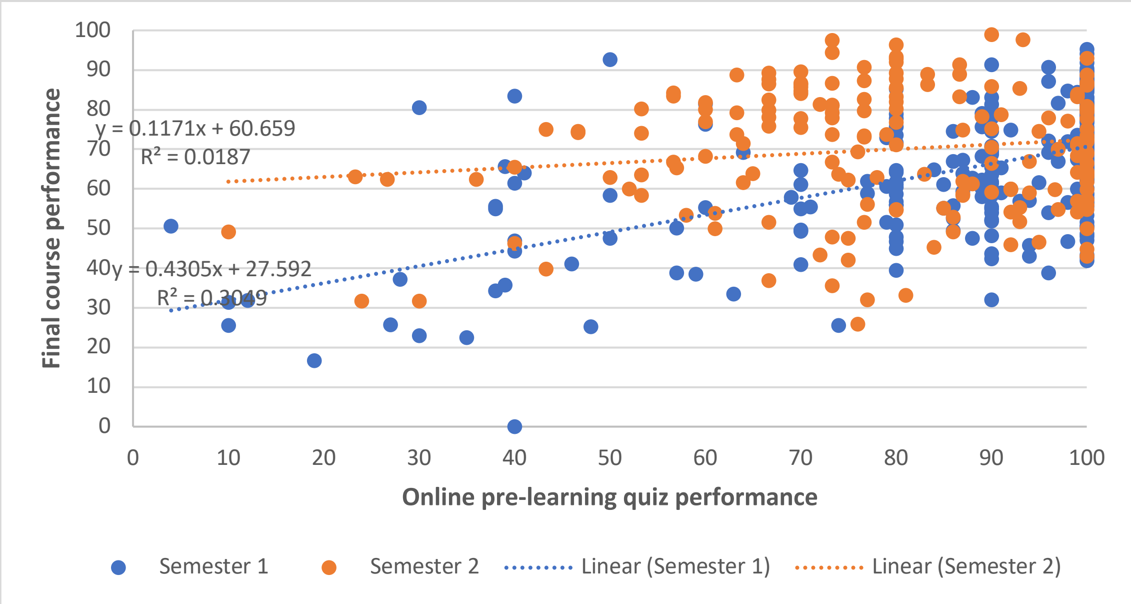

Figure F.5. Comparison of performance between pre-learning quiz and final course performance.

Appendix G: Appendix G: One-way ANOVA analyses and post-hoc Tukey's *t*-test comparison of various academic performance measures across the engagement groups on a cohort and course level for Group B_1

Table G.1. ANOVA comparisons of academic performance in the end of semester 1 examination for all intermediate chemistry students across the three engagement groups for Group B_1.

	n	M	SD	Tukey's HSD Comparisons		
				LE	ME	HE
LE	88	46.67	23.07	-		
ME	87	56.63	19.09	$p = 0.004$**	-	
HE	87	61.65	18.71	$p < 0.001$***	$p = 0.237$	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement ** $p < 0.01$, ***$p < 0.001$.

Table G.2. ANOVA comparisons of academic performance in the end of semester 2 examination for all intermediate chemistry students across the three engagement groups for Group B_1.

	n	M	SD	Tukey's HSD Comparisons		
				LE	ME	HE
LE	63	54.32	22.57	-		
ME	57	62.79	26.68	$p = 0.131$	-	
HE	59	70.58	22.42	$p = 0.001$***	$p = 0.188$	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, ***$p < 0.001$.

Table G.3. ANOVA comparisons of overall course performance in semester 1 for all intermediate chemistry students across the three engagement groups for Group B_1.

	n	M	SD	Tukey's HSD Comparisons		
				LE	ME	HE
LE	88	39.83	16.02	-		
ME	87	47.88	11.75	$p < 0.001$***	-	
HE	87	51.05	11.77	$p < 0.001$***	$p = 0.262$	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, ***$p < 0.001$.

Table G.4. ANOVA comparisons of overall course performance in semester 2 for all intermediate chemistry students across the three engagement groups for Group B_1.

	n	M	SD	Tukey's HSD Comparisons		
				LE	ME	HE
LE	63	43.69	14.12	-		
ME	57	50.72	15.65	$p = 0.021$*	-	
HE	59	55.38	12.83	$p < 0.001$***	$p = 0.185$	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement *$p < 0.05$, ***$p < 0.001$.

Table G.5. ANOVA comparisons of semester 1academic performance for CHEM2401 students across the three engagement groups for Group B_1.

End of semester examination				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	63	39.83	21.00	-		
ME	55	49.14	14.55	$p = 0.023$*	-	
HE	54	55.89	20.32	$p < 0.001$***	$p = 0.152$	-

Overall course performance				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	63	35.18	14.57	-		
ME	55	43.17	9.07	$p = 0.002$***	-	
HE	54	47.52	12.78	$p < 0.001$***	$p = 0.166$	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement * $p < 0.05$, ***$p < 0.001$.

Table G.6. ANOVA comparisons of semester 1 academic performance for CHEM2911 students across the three engagement groups for Group B_1.

End of semester examination				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	20	60.25	19.30	-		
ME	29	67.00	18.49	$p = 0.327$	-	
HE	32	70.94	10.97	$p = 0.059$	$p = 0.610$	-
						-

Overall course performance				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	20	49.07	13.88	-		
ME	29	54.49	10.97	$p = 0.185$	-	
HE	32	56.75	6.86	$p = 0.031$*	$p = 0.667$	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, *$p < 0.05$.

Table G.7. ANOVA comparisons of semester 2 academic performance for CHEM2402 students across the three engagement groups for Group B_1.

End of semester examination				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	39	48.67	16.18	-		
ME	31	50.82	24.59	$p = 0.898$	-	
HE	27	65.25	19.79	$p = 0.004$**	$p = 0.021$*	-

Overall course performance				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	39	39.91	10.55	-		
ME	31	43.65	14.62	$p = 0.420$	-	
HE	27	51.99	11.76	$p < 0.001$***	$p = 0.031$*	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, *$p < 0.05$ **, $p < 0.01$, ***$p < 0.001$.

Table G.8. ANOVA comparisons of semester 2 academic performance for CHEM2912 students across the three engagement groups for Group B_1.

End of semester examination				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	21	63.74	27.58	-		
ME	24	81.62	14.44	$p = 0.023$*	-	
HE	31	76.65	22.42	$p = 0.105$	$p = 0.689$	-

Overall course performance				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	21	49.67	17.05	-		
ME	24	61.58	9.44	$p = 0.010$**	-	
HE	31	58.96	12.72	$p = 0.039$*	$p = 0.747$	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, *$p < 0.05$, ** $p < 0.01$.

Appendix H: Comparison of performance between pre-learning quiz and other course assessment for Group B_2

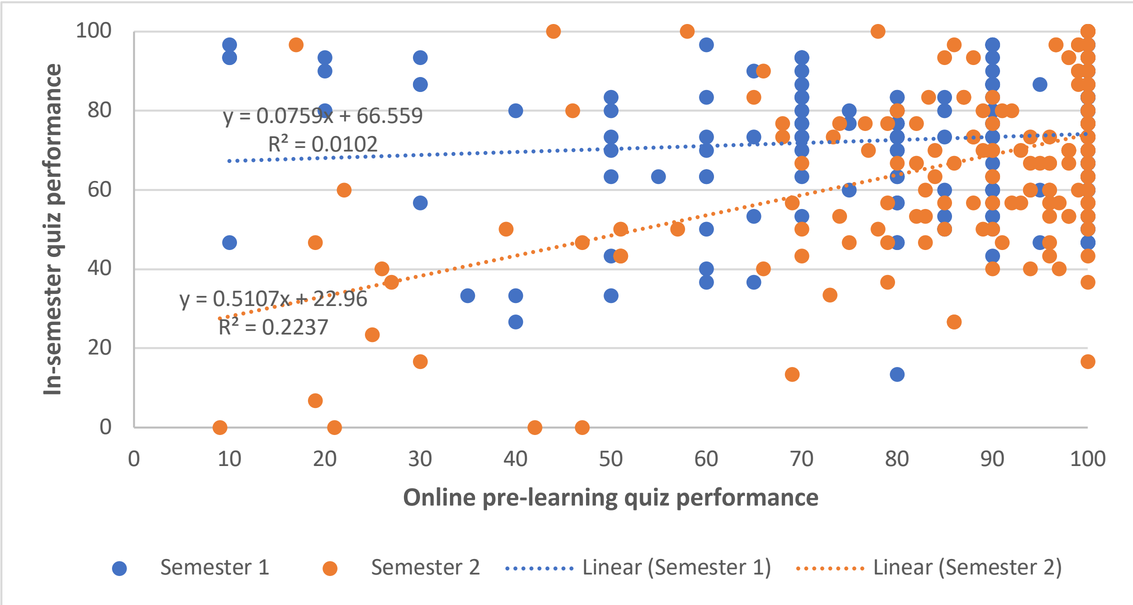

Figure H.1. Comparison of performance between pre-learning quiz and in-semester quiz.

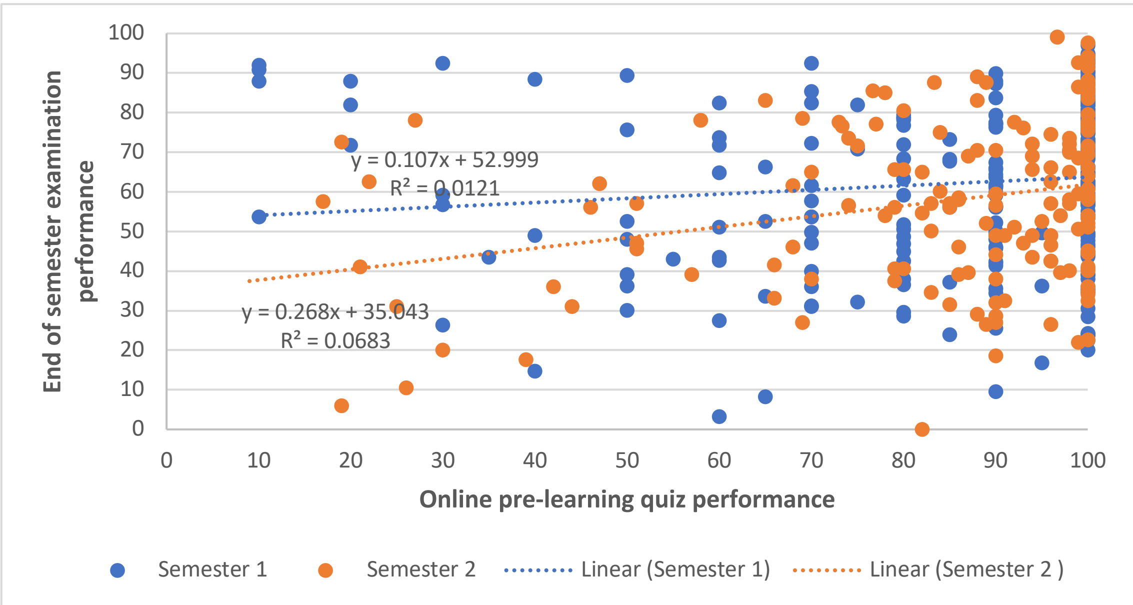

Figure H.2. Comparison of performance between pre-learning quiz and end of semester examination.

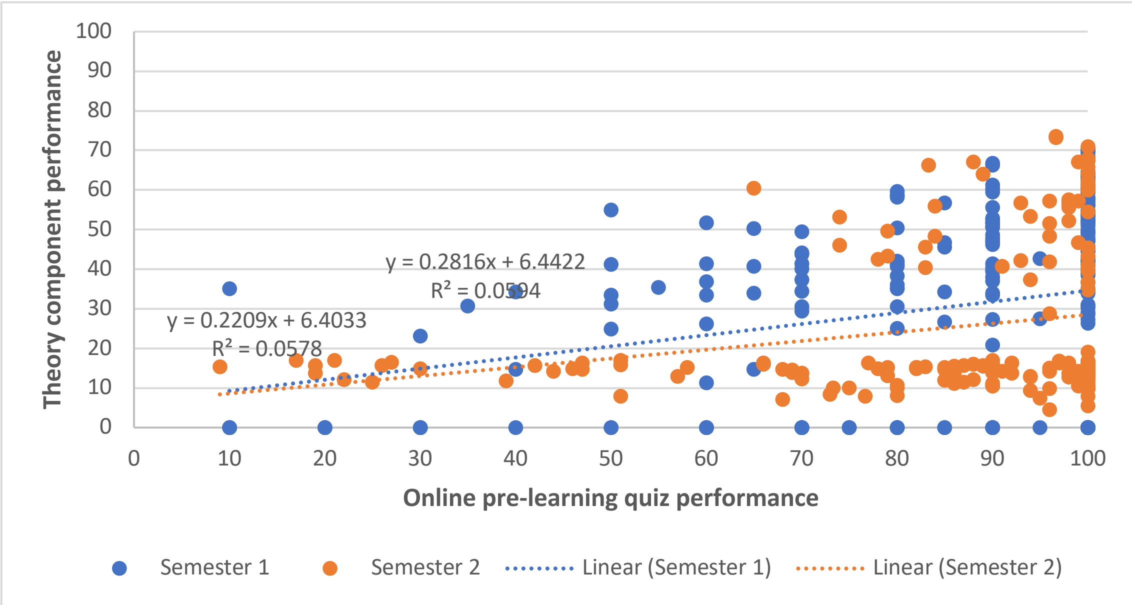

Figure H.3. Comparison of performance between pre-learning quiz and theory component.

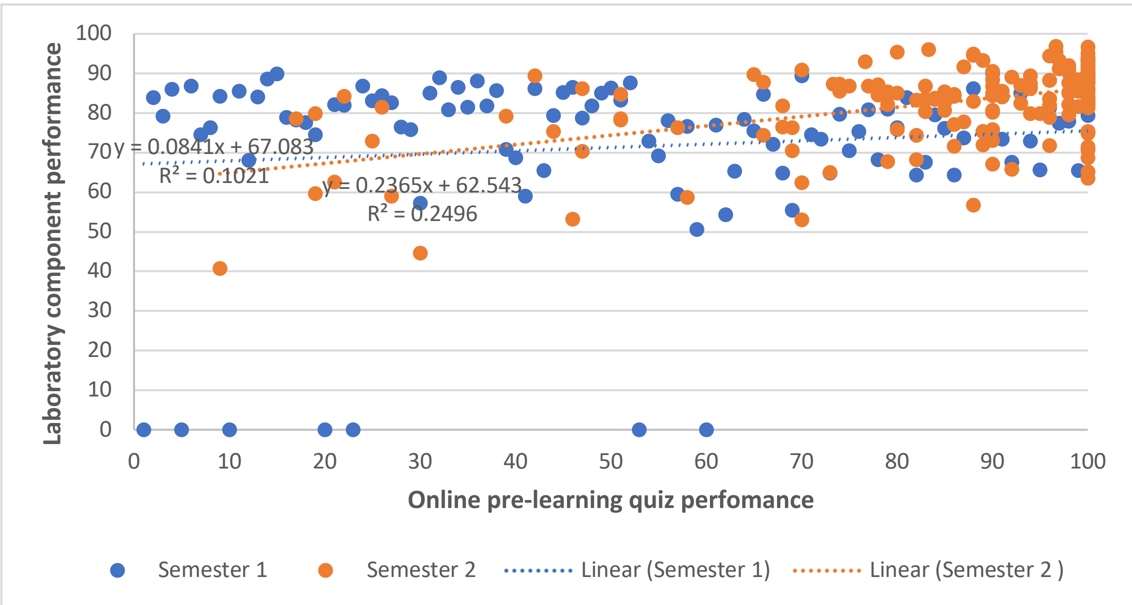

Figure H.4. Comparison of performance between pre-learning quiz and laboratory component.

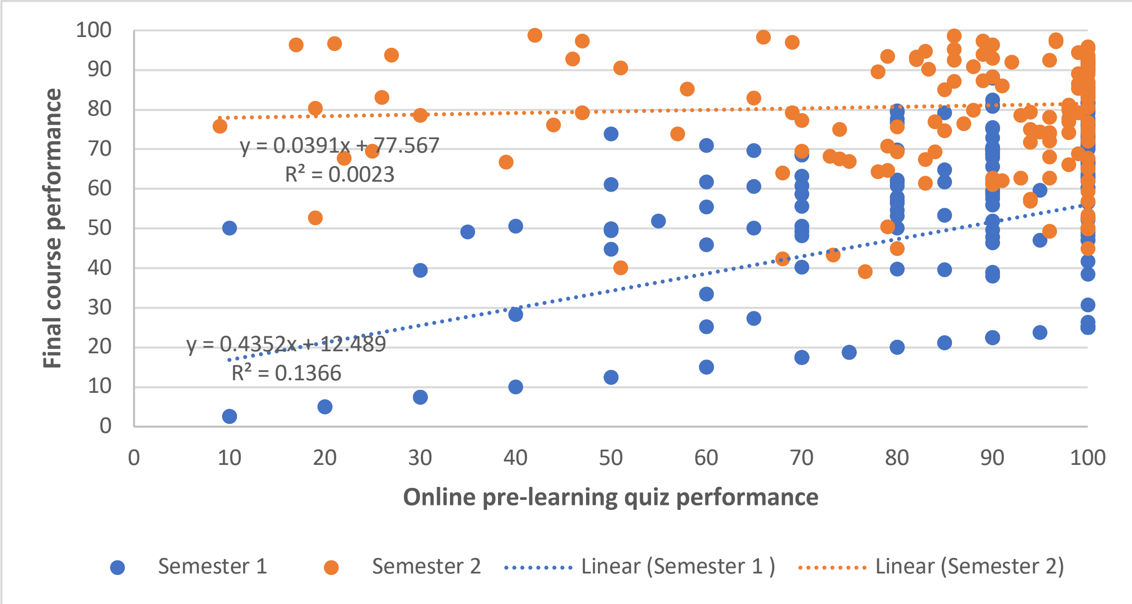

Figure H.5. Comparison of performance between pre-learning quiz and final course performance.

Appendix I: One-way ANOVA analyses and post-hoc Tukey's *t*-test comparison of various academic performance measures across the engagement groups on a cohort and course level for Group B_2

Table I.1. ANOVA comparisons of academic performance in the end of semester 1 examination for all intermediate chemistry students across the three engagement groups for Group B_2.

				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	82	56.06	21.51	-		
ME	79	61.21	20.16	$p = 0.227$	-	
HE	74	69.96	17.25	$p < 0.001$***	$p = 0.018$*	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, *$p < 0.05$, ***$p < 0.001$.

Table I.2. ANOVA comparisons of academic performance in the end of semester 2 examination for all intermediate chemistry students across the three engagement groups for Group B_2.

				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	59	54.73	23.84	-		
ME	61	52.97	18.30	$p = 0.879$	-	
HE	54	65.72	18.25	$p = 0.011$*	$p = 0.002$**	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, *$p < 0.05$, **$p < 0.01$.

Table I.3. ANOVA comparisons of overall course performance in semester 1 for all intermediate chemistry students across the three engagement groups for Group B_2.

				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	82	45.87	13.97	-		
ME	79	50.06	12.40	$p = 0.087$	-	
HE	74	55.80	10.74	$p < 0.001$***	$p = 0.014$*	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, *$p < 0.05$, ***$p < 0.001$.

Table I.4. ANOVA comparisons of overall course performance in semester 2 for all intermediate chemistry students across the three engagement groups for Group B_2.

				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	59	43.83	15.63	-		
ME	61	44.50	11.69	$p = 0.957$	-	
HE	54	52.74	11.19	$p = 0.001$***	$p = 0.003$**	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement, ** $p < 0.01$, ***$p < 0.001$.

Table I.5. ANOVA comparisons of semester 1 academic performance for CHEM2401 students across the three engagement groups for Group B_2.

End of semester examination				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	49	43.60	16.71	-		
ME	55	57.61	20.51	$p < 0.001$***	-	
HE	51	65.44	17.12	$p < 0.001$***	$p = 0.074$	-

Overall course performance				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	49	37.71	10.53	-		
ME	55	47.89	12.61	$p < 0.001$***	-	
HE	51	53.03	10.78	$p < 0.001$***	$p = 0.056$	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement ***$p < 0.001$.

Table I.6. ANOVA comparisons of semester 1 academic performance for CHEM2911 students across the three engagement groups for Group B_2.

End of semester examination				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	19	67.90	10.83	-		
ME	23	68.37	16.45	$p = 0.994$	-	
HE	18	77.41	13.27	$p = 0.104$	$p = 0.107$	-

Overall course performance				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	19	53.17	7.65	-		
ME	23	54.33	10.20	$p = 0.907$	-	
HE	18	60.46	8.10	$p = 0.039$*	$p = 0.079$	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement *$p < 0.05$.

Table I.7. ANOVA comparisons of semester 2 academic performance for CHEM2402 students across the three engagement groups for Group B_2.

End of semester examination				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	34	42.29	19.04	-		
ME	49	50.44	17.78	$p = 0.097$	-	
HE	37	57.96	15.55	$p = 0.001$**	$p = 0.124$	-

Overall course performance				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	34	35.61	13.41	-		
ME	49	43.08	11.45	$p = 0.011$*	-	
HE	37	47.91	9.26	$p < 0.001$***	$p = 0.132$	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement *$p < 0.05$ ** $p < 0.01$ ***$p < 0.001$.

Table I.8. ANOVA comparisons of semester 2 academic performance for CHEM2912 students across the three engagement groups for Group B_2.

End of semester examination				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	18	66.17	14.58	-		
ME	11	60.68	15.76	$p = 0.544$	-	
HE	14	79.92	9.66	$p = 0.018$*	$p = 0.003$**	-
						-

Overall course performance				Tukey's HSD Comparisons		
	n	M	SD	LE	ME	HE
LE	18	50.94	9.66	-		
ME	11	48.50	9.82	$p = 0.752$	-	
HE	14	61.57	6.59	$p = 0.004$**	$p = 0.002$**	-

Note. M = mean, SD = standard deviation, LE = low engagement, ME = moderate engagement, HE = high engagement *$p < 0.05$ ** $p < 0.01$.

Appendix J: One-way ANOVA analyses and post-hoc Tukey's *t*-test comparison of various academic performance measures across the behavioural viewing groups on a cohort and course level for Groups B_1 and B_2

Table J.1. ANOVA comparisons of online pre-learning quiz performance across behavioural viewing groups for Group B_1 across both semesters.

	Semester 1			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	78	98.91	3.26	-			*H****
$V_{<5}$	122	89.37	12.69	$p < 0.001$***	-		
$V_{\geq 5}$	59	67.51	30.68	$p < 0.001$***	$p < 0.001$***	-	
V_N	3	66.67	24.17	$p = 0.009$**	$p = 0.110$	$p = 0.100$***	-

	Semester 2			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	117	82.73	16.16	-			
$V_{<5}$	57	73.98	20.14	$p = 0.007$***	-		
$V_{\geq 5}$	5	51.73	22.20	$p < 0.001$***	$p < 0.021$**	-	
V_N	N/A	N/A	N/A				-

Note. M = mean, SD = standard deviation, V_{All} = all videos, $V_{<5}$ = less than five videos, $V_{\geq 5}$ = greater or equal to five videos and V_N = no video views, ** $p < 0.01$,***$p < 0.001$.

Table J.1. ANOVA comparisons of online pre-learning quiz performance across behavioural viewing groups for Group B_2 across both semesters

	Semester 1			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	80	99.06	3.29	-			H***
$V_{<5}$	119	86.05	14.57	$p < 0.001$***	-		
$V_{\geq 5}$	31	54.52	28.06	$p < 0.001$***	$p < 0.001$***	-	
V_N	5	58.00	40.25	$p < 0.001$***	$p < 0.001$***	$p = 0.967$	-

	Semester 2			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	83	96.45	5.63	-			
$V_{<5}$	70	81.75	15.42	$p < 0.001$***	-		
$V_{\geq 5}$	21	48.62	30.43	$p < 0.001$***	$p < 0.001$***	-	
V_N	N/A	N/A	N/A	-	-		-

Note. M = mean, SD = standard deviation, V_{All} = all videos, $V_{<5}$ = less than five videos, $V_{\geq 5}$ = greater or equal to five videos and V_N = no video views, ** $p < 0.01$,*** $p < 0.001$.

Table J.2. ANOVA comparisons of online in-semester quiz performance across behavioural viewing groups for Group B_1 across both semesters.

	Semester 1			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	78	75.85	16.60	-			
$V_{<5}$	122	71.69	18.42	$p = 0.453$	-		
$V_{\geq 5}$	59	68.70	24.39	$p = 0.145$	$p = 0.766$	-	
V_N	3	70.00	17.64	$p = 0.145$	$p = 0.999$	$p = 0.999$	-

	Semester 2			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	117	80.80	20.91	-			
$V_{<5}$	57	64.56	21.59	$p < 0.001$***	-		
$V_{\geq 5}$	5	31.33	24.68	$p < 0.001$***	$p = 0.003$**	-	
V_N	N/A	N/A	N/A				-

Note. M = mean, SD = standard deviation, V_{All} = all videos, $V_{<5}$ = less than five videos, $V_{\geq 5}$ = greater or equal to five videos and V_N = no video views, ** $p < 0.01$,***$p < 0.001$.

Table J.3. ANOVA comparisons of online in-semester quiz performance across behavioural viewing groups for Group B_2 across both semesters.

	Semester 1			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	80	75.29	12.86	-			
$V_{<5}$	119	71.85	16.57	$p = 0.439$	-		
$V_{\geq 5}$	31	71.50	19.55	$p = 0.673$	$p = 1$	-	
V_N	5	76.00	18.16	$p = 1$	$p = 0.940$	$p = 0.936$	-

	Semester 2			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	83	71.29	16.87	-			
$V_{<5}$	70	63.43	22.39	$p = 0.078$	-		
$V_{\geq 5}$	21	55.71	36.58	$p = 0.013$*	$p = 0.347$	-	
V_N	N/A	N/A	N/A				-

Note. M = mean, SD = standard deviation, V_{All} = all videos, $V_{<5}$ = less than five videos, $V_{\geq 5}$ = greater or equal to five videos and V_N = no video views, * $p < 0.05$.

Table J.4. ANOVA comparisons of end of semester examination performance across behavioural viewing groups for Group B_1 across both semesters.

	Semester 1			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	78	58.07	19.12	-			
$V_{<5}$	122	55.33	19.42	$p = 0.806$	-		
$V_{\geq 5}$	59	49.25	26.47	$p = 0.075$	$p = 0.267$	-	
V_N	3	70.00	9.17	$p = 0.771$	$p = 0.633$	$p = 0.345$	-

	Semester 2			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	117	67.50	23.19	-			
$V_{<5}$	57	52.63	24.37	$p < 0.001$***	-		
$V_{\geq 5}$	5	53.48	32.25	$p = 0.403$	$p = 0.997$	-	
V_N	N/A	N/A	N/A				-

Note. M = mean, SD = standard deviation, V_{All} = all videos, $V_{<5}$ = less than five videos, $V_{\geq 5}$ = greater or equal to five videos and V_N = no video views,****p* < 0.001.

Table J.5. ANOVA comparisons of end of semester examination performance across behavioural viewing groups for Group B_2 across both semesters.

	Semester 1			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	80	67.19	17.81	-			
$V_{<5}$	119	59.21	21.00	$p = 0.035$*	-		
$V_{\geq 5}$	31	59.47	23.57	$p = 0.276$	$p = 1$	-	
V_N	5	69.02	17.20	$p = 0.997$	$p = 0.715$	$p = 0.763$	-

	Semester 2			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	81	60.54	18.85	-			
$V_{<5}$	69	55.15	21.14	$p = 0.254$	-		
$V_{\geq 5}$	19	56.74	26.47	$p = 0.752$	$p = 0.953$	-	
V_N	N/A	N/A	N/A				-

Note. M = mean, SD = standard deviation, V_{All} = all videos, $V_{<5}$ = less than five videos, $V_{\geq 5}$ = greater or equal to five videos and V_N = no video views, * $p < 0.05$.

Table J.6. ANOVA comparisons of overall academic performance across behavioural viewing groups for Group B_1 across both semesters.

	Semester 1			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	78	49.42	11.78	-			
$V_{<5}$	122	46.56	12.42	$p = 0.485$	-		
$V_{\geq 5}$	59	41.04	18.57	$p = 0.003$**	$p = 0.060$	-	
V_N	3	52.17	8.00	$p = 0.987$	$p = 0.900$	$p = 0.527$	-

	Semester 2			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	117	53.50	13.75	-			-
$V_{<5}$	57	42.93	14.44	$p < 0.001$***	-		-
$V_{\geq 5}$	5	40.76	14.96	$p = 0.121$	$p = 0.942$	-	
V_N	N/A	N/A	N/A				-

Note. M = mean, SD = standard deviation, V_{All} = all videos, $V_{<5}$ = less than five videos, $V_{\geq 5}$ = greater or equal to five videos and V_N = no video views, ** $p < 0.01$,*** $p < 0.001$.

Table J.7. ANOVA comparisons of overall academic performance across behavioural viewing groups for Group B_2 across both semesters.

	Semester 1			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	80	54.36	10.71	-			
$V_{<5}$	119	48.47	13.29	$p = 0.009$**	-		
$V_{\geq 5}$	31	46.93	15.79	$p = 0.033$*	$p = 0.934$	-	
V_N	5	54.41	11.57	$p = 1$	$p = 0.686$	$p = 0.566$	-

	Semester 2			Tukey's HSD Comparisons			
	n	M	SD	V_{All}	$V_{<5}$	$V_{\geq 5}$	V_N
V_{All}	83	49.28	12.40	-			
$V_{<5}$	70	44.40	13.75	$p = 0.093$	-		
$V_{\geq 5}$	21	38.83	21.68	$p = 0.009$**	$p = 0.264$	-	
V_N	N/A	N/A	N/A				-

Note. M = mean, SD = standard deviation, V_{All} = all videos, $V_{<5}$ = less than five videos, $V_{\geq 5}$ = greater or equal to five videos and V_N = no video views, * $p < 0.05$,**$p < 0.01$.

Appendix K: One-way ANOVA analyses and post-hoc Tukey's *t*-test comparison of various academic performance measures across the behavioural quiz groups on a cohort and course level for Groups B_1 and B_2

Table K.1. ANOVA comparisons of online pre-learning quiz performance across behavioural quiz groups for Group B_1 across both semesters.

	Semester 1			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	145	98.06	8.93	-		
$Q_{<5}$	92	82.76	11.48	$p < 0.001$***	-	
$Q_{\geq 5}$	25	38.76	20.67	$p < 0.001$***	$p < 0.001$***	-
						-

	Semester 2			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	130	80.86	17.67	-		
$Q_{<5}$	47	75.11	20.04	$p = 0.160$	-	
$Q_{\geq 5}$	2	56.33	28.76	$p = 0.150$	$p = 0.336$	-

Note. M = mean, *SD* = standard deviation, Q_{All} = all quizzes, $Q_{<5}$ = less than five quizzes, $Q_{\geq 5}$ = greater or equal to five quizzes, ****p* < 0.001.

Table K.2. ANOVA comparisons of online pre-learning quiz performance across behavioural quiz groups for Group B_2 across both semesters.

	Semester 1			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	124	99.72	1.47	-		
$Q_{<5}$	91	78.63	11.36	$p < 0.001$***	-	
$Q_{\geq 5}$	20	31.25	14.86	$p < 0.001$***	$p < 0.001$***	-
						-
	Semester 2			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	97	80.86	17.67	-		
$Q_{<5}$	56	75.11	20.04	$p = 0.160$	-	
$Q_{\geq 5}$	2	56.33	28.76	$p = 0.150$	$p = 0.336$	-

Note. M = mean, *SD* = standard deviation, Q_{All} = all quizzes, $Q_{<5}$ = less than five quizzes, $Q_{\geq 5}$ = greater or equal to five quizzes, ***$p < 0.001$

Table K.3. ANOVA comparisons of online in-semester quiz performance across behavioural quiz groups for Group B_1 across both semesters.

	Semester 1			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	145	76.51	16.50	-		
$Q_{<5}$	92	70.07	18.41	$p = 0.026$*	-	
$Q_{\geq 5}$	25	55.47	28.18	$p < 0.001$***	$p = 0.002$**	-
						-
	Semester 2			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	130	80.86	17.67	-		
$Q_{<5}$	47	75.11	20.04	$p < 0.001$***	-	
$Q_{\geq 5}$	2	56.33	28.76	$p = 0.002$**	$p = 0.031$*	-

Note. M = mean, *SD* = standard deviation, Q_{All} = all quizzes, $Q_{<5}$ = less than five quizzes, $Q_{\geq 5}$ = greater or equal to five quizzes, ***$p < 0.001$.

Table K.4. ANOVA comparisons of online in-semester quiz performance across behavioural quiz groups for Group B_2 across both semesters.

	Semester 1			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	124	75.65	1.22	-		
$Q_{<5}$	91	70.29	1.69	$p = 0.038$*	-	
$Q_{\geq 5}$	20	69.67	5.55	$p = 0.256$	$p = 0.986$	-
						-
	Semester 2			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	97	80.86	17.67	-		
$Q_{<5}$	56	75.11	20.04	$p = 0.024$*	-	
$Q_{\geq 5}$	2	56.33	28.76	$p = 0.022$*	$p = 0.710$	-

Note. M = mean, *SD* = standard deviation, Q_{All} = all quizzes, $Q_{<5}$ = less than five quizzes, $Q_{\geq 5}$ = greater or equal to five quizzes, *$p < 0.05$.

Table K.5. ANOVA comparisons of end of semester examination performance across behavioural quiz groups for Group B_1 across both semesters.

	Semester 1			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	145	59.91	18.86	-		
$Q_{<5}$	92	52.48	19.99	$p = 0.016$*	-	
$Q_{\geq 5}$	25	35.22	26.22	$p < 0.001$***	$p < 0.001$***	-
						-
	Semester 2			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	130	66.18	23.70	-		
$Q_{<5}$	47	52.66	24.62	$p = 0.003$**	-	
$Q_{\geq 5}$	2	43.06	34.74	$p = 0.369$	$p = 0.845$	-

Note. M = mean, *SD* = standard deviation, Q_{All} = all quizzes, $Q_{<5}$ = less than five quizzes, $Q_{\geq 5}$ = greater or equal to five quizzes,*$p < 0.05$ **, $p < 0.01$, ***$p < 0.001$.

Table K.6. ANOVA comparisons of end of semester examination performance across behavioural quiz groups for Group B_2 across both semesters.

	Semester 1			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	124	66.88	19.23	-		
$Q_{<5}$	91	55.41	19.43	$p < 0.001$***	-	
$Q_{\geq 5}$	20	63.72	25.23	$p = 0.786$	$p = 0.210$	-
						-
	Semester 2			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	95	80.86	17.67	-		
$Q_{<5}$	55	75.11	20.04	$p = 0.413$	-	
$Q_{\geq 5}$	19	56.33	28.76	$p = 0.997$	$p = 0.651$	-

Note. M = mean, *SD* = standard deviation, Q_{All} = all quizzes, $Q_{<5}$ = less than five quizzes, $Q_{\geq 5}$ = greater or equal to five quizzes, ***$p < 0.001$

Table K.7. ANOVA comparisons of overall academic performance across behavioural quiz groups for Group B_1 across both semesters.

	Semester 1			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	145	50.40	11.72	-		
$Q_{<5}$	92	44.21	12.47	$p < 0.001$***	-	
$Q_{\geq 5}$	25	29.50	18.46	$p < 0.001$***	$p < 0.001$***	-
						-
	Semester 2			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	117	53.50	13.75	-		
$Q_{<5}$	57	42.93	14.44	$p = 0.003$**	-	
$Q_{\geq 5}$	5	40.76	19.59	$p = 0.369$	$p = 0.845$	-

Note. M = mean, *SD* = standard deviation, Q_{All} = all quizzes, $Q_{<5}$ = less than five quizzes, $Q_{\geq 5}$ = greater or equal to five quizzes,**$p < 0.01$, ***$p < 0.001$.

Table K.8. ANOVA comparisons of overall academic performance across behavioural quiz groups for Group B_2 across both semesters.

	Semester 1			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	124	54.28	11.39	-		
$Q_{<5}$	91	45.49	12.24	$p < 0.001$***	-	
$Q_{\geq 5}$	20	48.81	18.54	$p = 0.165$	$p = 0.528$	-
						-
	Semester 2			Tukey's HSD Comparisons		
	n	M	SD	Q_{All}	$Q_{<5}$	$Q_{\geq 5}$
Q_{All}	97	48.71	12.20	-		
$Q_{<5}$	56	43.55	13.99	$p = 0.087$	-	
$Q_{\geq 5}$	21	40.49	22.91	$p = 0.050$*	$p = 0.685$	-

Note. M = mean, *SD* = standard deviation, Q_{All} = all quizzes, $Q_{<5}$ = less than five quizzes, $Q_{\geq 5}$ = greater or equal to five quizzes, ***$p < 0.001$.

Appendix L: One-way ANOVA analyses and post-hoc Tukey's *t*-test comparison of various academic performance measures across the behavioural pattern groups on a cohort level for Groups B_1 and B_2

Table L.1. ANOVA comparison of academic performance across behavioural pattern groups on a cohort level for Group B_1 for semester 1.

				Tukey's HSD Comparisons			
Overall pre-learning quiz	*n*	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	18	90.28	17.49	-			
BP_2	166	93.14	11.74	$p = 0.922$	-		
BP_3	40	89.58	14.67	$p = 1$	$p = 0.596$	-	
BP_4	18	79.17	20.97	$p = 0.123$	$p < 0.001$***	$p = 0.069$	-
BP_6	20	35.30	18.36	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***
				Tukey's HSD Comparisons			
End of semester examination	*n*	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	18	67.58	14.57	-			
BP_2	166	55.04	20.12	$p = 0.090$	-		
BP_3	40	61.98	19.04	$p = 0.862$	$p = 0.289$	-	
BP_4	18	49.19	16.09	$p = 0.050$	$p = 0.767$	$p = 0.168$	-
BP_6	20	33.95	27.89	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***	$p = 0.137$
				Tukey's HSD Comparisons			
Overall course performance	*n*	M	SD	BP_1	BP_2	- BP_3	- BP_4
BP_1	18	54.04	9.55	-			
BP_2	166	46.95	12.68	$p = 0.182$	-		
BP_3	40	50.79	12.31	$p = 0.904$	$p = 0.447$	-	
BP_4	18	41.36	11.28	$p = 0.030$*	$p = 0.415$	$p = 0.081$	-
BP_6	20	28.53	19.37	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***	$p = 0.022$*

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_1 = Q, BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_5 = V and BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access,* $p < 0.05$, ***$p < 0.001$.

Table L.2. ANOVA comparison of academic performance across behavioural pattern groups on a cohort level for Group B_1 for semester 2.

				Tukey's HSD Comparisons		
Overall pre-learning quiz	*n*	M	SD	BP_2	BP_3	BP_4
BP_2	158	80.75	16.44	-		
BP_3	10	82.57	21.33	$p = 0.988$	-	
BP_4	4	64.25	17.29	$p = 0.236$	$p = 0.279$	-
BP_6	7	44.76	27.83	$p < 0.001$***	$p < 0.001$***	$p = 0.276$
				Tukey's HSD Comparisons		
End of semester examination	*n*	M	SD	BP_2	BP_3	BP_4
BP_2	158	62.05	24.55	-		
BP_3	10	69.38	26.84	$p = 0.803$	-	
BP_4	4	66.00	26.57	$p = 0.989$	$p = 0.996$	-
BP_6	7	57.57	27.92	$p = 0.966$	$p = 0.770$	$p = 0.949$
				Tukey's HSD Comparisons		
Overall course performance	*n*	M	SD	BP_2	BP_3	BP_4
BP_2	158	49.88	14.76	-		
BP_3	10	53.64	15.94	$p = 0.868$	-	
BP_4	4	49.80	17.73	$p = 1.000$	$p = 0.973$	-
BP_6	7	42.01	17.46	$p = 0.526$	$p = 0.395$	$p = 0.960$

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_5 = V and BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access, ***$p < 0.001$.

Table L.3. ANOVA comparison of academic performance across behavioural pattern groups on a cohort level for Group B_2 for semester 1.

				Tukey's HSD Comparisons			
Overall pre-learning quiz	*n*	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	7	92.86	9.51	-			
BP_2	169	92.84	10.85	$p = 1$	-		
BP_3	36	82.50	16.01	$p = 0.283$	$p < 0.001$***	-	
BP_4	3	70.00	26.46	$p = 0.062$	$p < 0.001$***	$p = 0.497$	-
BP_6	20	34.92	15.82	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***
				Tukey's HSD Comparisons			
End of semester examination	*n*	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	7	67.44	25.97	-			
BP_2	169	60.19	19.99	$p = 0.939$	-		
BP_3	36	68.58	18.24	$p = 1$	$p = 0.218$	-	
BP_4	3	67.14	32.30	$p = 1$	$p = 0.992$	$p = 1$	-
BP_6	20	61.90	23.18	$p = 0.998$	$p = 0.907$	$p = 0.997$	$p = 0.999$
				Tukey's HSD Comparisons			
Overall course performance	*n*	M	SD	BP_1	BP_2	- BP_3	- BP_4
BP_1	7	53.96	15.50	-			
BP_2	169	49.64	12.37	$p = 0.955$	-		
BP_3	36	53.61	12.16	$p = 1$	$p = 0.553$	-	
BP_4	3	52.47	23.94	$p = 1$	$p = 0.999$	$p = 1$	-
BP_6	20	47.36	16.70	$p = 0.325$	$p = 0.370$	$p = 1$	$p = 1$

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_1 = Q, BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_5 = V and BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access, * $p < 0.05$ ***$p < 0.001$.

Table L.4. ANOVA comparison of academic performance across behavioural pattern groups on a cohort level for Group B_2 for semester 2.

				Tukey's HSD Comparisons		
Overall pre-learning quiz	*n*	M	SD	BP_2	BP_3	BP_4
BP_2	132	91.94	10.20	-		
BP_3	14	79.00	20.10	$p = 0.020$*	-	
BP_4	9	60.89	20.24	$p < 0.001$***	$p = 0.039$*	-
BP_6	19	50.47	33.38	$p < 0.001$***	$p < 0.001$***	$p = 0.363$
				Tukey's HSD Comparisons		
End of semester examination	*n*	M	SD	BP_2	BP_3	BP_4
BP_2	130	56.44	19.44	-		
BP_3	14	69.54	22.23	$p = 0.108$	-	
BP_4	9	48.67	20.61	$p = 0.726$	$p = 0.103$	-
BP_6	19	63.91	26.15	$p = 0.492$	$p = 0.872$	$p = 0.726$
				Tukey's HSD Comparisons		
Overall course performance	*n*	M	SD	BP_2	BP_3	BP_4
BP_2	132	46.61	12.46	-		
BP_3	14	53.11	15.24	$p = 0.376$	-	
BP_4	9	35.34	15.40	$p = 0.108$	$p = 0.973$	-
BP_6	19	42.12	23.43	$p = 0.583$	$p = 0.395$	$p = 0.960$

Note. M = mean, SD = standard deviation, BP = behaviour pattern where $BP_2 = Q > V$, $BP_3 = Q = V$, $BP_4 = Q < V$, $BP_5 = V$ and BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access, ***$p < 0.001$.

Appendix M: One-way ANOVA analyses and post-hoc Tukey's *t*-test comparison of various academic performance measures across the behavioural pattern groups on a course level for Groups B_1 and B_2

Table M.8. ANOVA comparison of academic performance across behavioural pattern groups in CHEM2401 for Group B_1.

				Tukey's HSD Comparisons			
Overall pre-learning quiz	*n*	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	10	86.60	21.30	-			
BP_2	111	91.76	13.46	$p = 0.862$	-		
BP_3	24	86.75	14.98	$p = 1.000$	$p = 0.628$	-	
BP_4	14	77.00	23.04	$p = 0.590$	$p = 0.011$**	$p = 0.362$	-
BP_6	13	33.92	22.40	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***
				Tukey's HSD Comparisons			
End of semester examination	*n*	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	10	66.25	16.86	-			
BP_2	111	48.40	17.94	$p = 0.026$*	-		
BP_3	24	53.40	19.63	$p = 0.326$	$p = 0.734$	-	
BP_4	14	45.71	15.30	$p = 0.052$	$p = 0.985$	$p = 0.713$	-
BP_6	13	21.08	19.60	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***	$p = 0.005$**
				Tukey's HSD Comparisons			
Overall course performance	*n*	M	SD	BP_1	BP_2	- BP_3	- BP_4
BP_1	10	52.60	11.19	-			
BP_2	111	42.80	11.49	$p = 0.086$	-		
BP_3	24	45.04	12.44	$p = 0.424$	$p = 0.913$	-	
BP_4	14	39.13	11.37	$p = 0.046$*	$p = 0.801$	$p = 0.559$	-
BP_6	13	19.31	12.28	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_1 = Q, BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_5 = V and BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access,* $p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table M.9. ANOVA comparison of academic performance across behavioural pattern groups in CHEM2402 for Group B_1.

				Tukey's HSD Comparisons		
Overall pre-learning quiz	*n*	M	SD	BP_2	BP_3	BP_4
BP_2	86	89.99	12.61	-		
BP_3	6	91.50	6.66	$p = 0.992$	-	
BP_4	3	59.00	16.82	$p < 0.001$***	$p = 0.002$**	-
BP_6	2	30.00	8.49	$p < 0.001$***	$p < 0.001$***	$p = 0.058$
				Tukey's HSD Comparisons		
End of semester examination	*n*	M	SD	BP_2	BP_3	BP_4
BP_2	86	53.33	20.11	-		
BP_3	6	63.52	33.24	$p = 0.671$	-	
BP_4	3	58.63	27.06	$p = 0.975$	$p = 0.988$	-
BP_6	2	45.88	30.76	$p = 0.961$	$p = 0.742$	$p = 0.914$
				Tukey's HSD Comparisons		
Overall course performance	*n*	M	SD	*BP_2	*BP_3	*BP_4
BP_2	86	44.33	12.42	-		
BP_3	6	50.98	19.30	$p = 0.628$	-	
BP_4	3	44.48	17.37	$p = 1.000$	$p = 0.896$	-
BP_6	2	30.56	19.65	$p = 0.460$	$p = 0.232$	$p = 0.651$

Note. M = mean, SD = standard deviation, BP = behaviour pattern where $BP_2 = Q > V$, $BP_3 = Q = V$, $BP_4 = Q < V$ and BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access, **$p < 0.01$, ***$p < 0.001$.

Table M.3. ANOVA comparison of academic performance across behavioural pattern groups in CHEM2911 for Group B_1.

				Tukey's HSD Comparisons			
Overall pre-learning quiz	*n*	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	8	94.88	10.76	-			
BP_2	55	95.95	6.29	$p = 0.997$	-		
BP_3	16	93.81	13.55	$p = 0.999$	$p = 0.906$	-	
BP_4	4	86.75	9.71	$p = 0.539$	$p = 0.246$	$p = 0.586$	-
BP_6	7	37.86	7.27	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***
				Tukey's HSD Comparisons			
End of semester examination	*n*	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	8	69.25	12.01	-			
BP_2	55	68.44	17.52	$p = 1.000$	-		
BP_3	16	74.84	7.56	$p = 0.934$	$p = 0.650$	-	
BP_4	4	61.38	14.07	$p = 0.935$	$p = 0.921$	$p = 0.589$	-
BP_6	7	57.86	25.88	$p = 0.669$	$p = 0.500$	$p = 0.163$	$p = 0.997$
				Tukey's HSD Comparisons			
Overall course performance	*n*	M	SD	BP_1	BP_2	- BP_3	- BP_4
BP_1	8	55.84	7.36	-			
BP_2	55	55.31	10.75	$p = 1.000$	-		
BP_3	16	59.41	4.94	$p = 0.933$	$p = 0.643$	-	
BP_4	4	49.18	7.53	$p = 0.837$	$p = 0.790$	$p = 0.410$	-
BP_6	7	45.64	18.99	$p = 0.335$	$p = 0.154$	$p = 0.037$	$p = 0.983$

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_1 = Q, BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_5 = V and BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access, ***$p < 0.001$.

Table M.4. ANOVA comparison of academic performance across behavioural pattern groups in CHEM2912 and CHEM2916 for Group B_1.

CHEM2912		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_2	69	69.23	13.26	74.60	23.76	57.57	14.03
BP_3	4	69.17	29.86	78.16	12.18	57.63	10.29
BP_4	1	80.00	-	88.13	-	65.77	-
BP_6	2	16.67	9.42	62.90	14.50	39.85	9.20

CHEM2916		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_1	3	93.33	11.55	88.34	8.50	66.61	5.36
BP_2	3	90.00	17.32	84.64	1.58	64.88	1.05
BP_3	3	90.00	17.32	89.73	8.86	67.85	4.66
BP_4	1	60.00	-	82.45	-	64.63	-
BP_6	10	24.00	13.50	84.113	10.71	64.88	5.47

Note. M = mean, SD = standard deviation, BP = behaviour pattern where $BP_2 = Q > V$, $BP_3 = Q = V$, $BP_4 = Q < V$, BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

Table M.5. ANOVA comparison of academic performance across behavioural pattern groups in CHEM2915 for Group B_1.

		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_1	1	100	-	91.50	-	69.41	-
BP_2	3	96.67	5.77	88.33	11.25	67.50	6.78
BP_3	2	60.00	0.00	73.75	2.47	58.34	2.89
BP_6	3	40.00	110.00	81.50	9.17	63.58	5.70

Note. M = mean, SD = standard deviation, BP = behaviour pattern where $BP_2 = Q > V$, $BP_3 = Q = V$, BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

Table M.10. ANOVA comparison of academic performance across behavioural pattern groups in CHEM2401 for Group B_2.

				Tukey's HSD Comparisons			
Overall pre-learning quiz	*n*	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	2	90.00	14.14	-			
BP_2	119	92.56	10.79	$p = 0.998$	-		
BP_3	24	79.38	16.24	$p = 0.764$	$p < 0.001$***	-	
BP_4	2	75.00	35.35	$p = 0.738$	$p = 0.267$	$p = 0.989$	-
BP_6	8	38.13	13.61	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***	$p = 0.002$**

				Tukey's HSD Comparisons			
End of semester examination	*n*	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	2	33.28	13.08	-			
BP_2	119	54.93	19.87	$p = 0.540$	-		
BP_3	24	65.38	18.15	$p = 0.182$	$p = 0.131$	-	
BP_4	2	59.49	41.66	$p = 0.675$	$p = 0.998$	$p = 0.994$	-
BP_6	8	43.86	18.64	$p = 0.961$	$p = 0.542$	$p = 0.064$	$p = 0.855$

				Tukey's HSD Comparisons			
Overall course performance	*n*	M	SD	BP_1	BP_2	- BP_3	- BP_4
BP_1	2	33.14	4.14	-			
BP_2	119	46.47	12.36	$p = 0.566$	-		
BP_3	24	51.33	12.27	$p = 0.282$	$p = 0.416$	-	
BP_4	2	46.39	30.45	$p = 0.827$	$p = 1.000$	$p = 0.983$	-
BP_6	8	33.14	11.93	$p = 1.000$	$p = 0.032$*	$p = 0.004$	$p = 0.667$

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_1 = Q, BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_5 = V and BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access, * $p < 0.05$, ** $p < 0.01$, ***$p < 0.001$.

Table M.7. ANOVA comparison of academic performance across behavioural pattern groups in CHEM2402 for Group B_2.

				Tukey's HSD Comparison		
Overall pre-learning quiz	*n*	M	SD	BP_2	BP_3	BP_4
BP_1	3	93.33	11.55			
BP_2	3	90.00	17.32	-		
BP_3	3	90.00	17.32	$p = 0.009$	-	
BP_4	1	60.00	-	$p < 0.001$***	$p = 0.\ 072$	-
BP_6	10	24.00	13.50	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***
				Tukey's HSD Comparisons		
End of semester examination	*n*	M	SD	BP_2	BP_3	BP_4
BP_1	3	88.34	8.50			
BP_2	3	84.64	1.58	-		
BP_3	3	89.73	8.86	$p = 0.509$	-	
BP_4	1	82.45	-	$p = 0.997$	$p = 0.675$	-
BP_6	10	84.13	10.71	$p = 0.508$	$p = 0.183$	$p = 0.802$
				Tukey's HSD Comparisons		
Overall course performance	*n*	M	SD	BP_2	- BP_3	- BP_4
BP_1	3	66.61	5.36			
BP_2	3	64.88	1.05	-		
BP_3	3	67.85	4.66	$p = 0.825$	-	
BP_4	1	64.63	-	$p = 0.352$	$p = 0.246$	-
BP_6	10	64.88	5.47	$p < 0.001$***	$p < 0.001$***	$p = 0.089$

Note. , M = mean, SD = standard deviation, BP = behaviour pattern where BP_1 = Q, BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_5 = V and BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access, ***$p < 0.001$.

Table M.8. ANOVA comparison of academic performance across behavioural pattern groups in CHEM2911 and CHEM2915 for Group B_2.

CHEM2911		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_1	19	81.58	20.55	67.90	10.83	53.17	7.65
BP_2	23	93.91	9.17	68.36	16.45	54.32	10.20
BP_3	18	97.78	6.47	77.41	13.27	60.46	8.10

CHEM2915		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_2	35	93.23	9.20	69.56	15.52	54.81	9.85
BP_3	3	77.00	21.28	83.17	9.39	60.99	9.111
BP_4	1	51.00	-	45.50	-	34.46	-
BP_6	4	32.25	16.48	62.00	7.44	44.07	1.59

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

Table M.11. ANOVA comparison of academic performance across behavioural pattern groups in CHEM2912 and CHEM2916 for Group B_2.

CHEM2912		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_2	35	93.23	9.43	70.44	14.82	55.39	9.39
BP_3	3	70.44	14.83	83.17	9.39	62.00	7.45
BP_4	1	51.50	-	45.50	-	43.33	-
BP_6	4	32.20	12.48	61.00	6.44	44.08	1.60

CHEM2916		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_2	2	98.34	2.35	95.25	5.30	71.93	2.19
BP_3	2	90.00	9.43	93.25	8.13	69.73	4.98
BP_6	7	90.00	12.61	88.81	7.54	65.51	5.03

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

Appendix N: One-way ANOVA analyses and post-hoc Tukey's *t*-test comparison of various academic performance measures of the varying behavioural pattern groups across the engagement groups on a course level for Groups B_1 and B_2

Table N.1. Academic performance of low engaged students across varying behavioural patterns for Group B_1 semester 1.

Overall pre-learning quiz				Tukey's HSD Comparisons			
	n	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	6	82	26.75	-			
BP_2	57	88.77	13.40	$p = 0.842$	-		
BP_3	4	59.25	1.5	$p = 0.157$		-	
BP_4	3	39.00	1.00	$p = 0.001$***	$p < 0.001$***	$p = 0.423$	-
BP_6	18	33.67	18.67	$p < 0.001$***	$p < 0.001$***	$p = 0.027$*	$p = 0.981$
End of semester examination				Tukey's HSD Comparisons			
	n	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	6	68.33	24.35	-			
BP_2	57	49.38	19.63	$p = 0.230$	-		
BP_3	4	60.75	15.79	$p = 0.982$	$p = 0.834$	-	
BP_4	3	32.50	13.76	$p = 0.123$	$p = 0.658$	$p = 0.405$	-
BP_6	18	30.01	25.50	$p = 0.002$**	$p = 0.009$**	$p = 0.073$	$p = 0.100$
Overall course performance				Tukey's HSD Comparisons			
	n	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	6	54.08	15.97	-			
BP_2	57	42.90	12.80	$p = 0.348$	-		
BP_3	4	47.40	12.80	$p = 0.947$	$p = 0.971$	-	
BP_4	3	27.11	8.23	$p = 0.059$	$p = 0.324$	$p = 0.328$	-
BP_6	18	25.78	17.51	$p < 0.001$***	$p < 0.001$***	$p = 0.050$*	$p = 1.000$

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_1 = Q ,BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access, **$p < 0.01$***$p < 0.001$.

Table N.2. Academic performance of moderately engaged students across varying behavioural patterns for Group B_1 semester 1.

Moderate engagement		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_1	6	90.50	12.13	66.17	8.35	52.78	5.98
BP_2	68	94.88	6.87	56.19	19.84	48.01	11.96
BP_3	5	81.80	8.73	53.20	15.37	44.17	9.57
BP_4	6	83.17	11.71	50.83	17.38	42.11	12
BP_6	2	50	0	68.75	32.17	53.27	23.53

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_1 = Q , BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

Table N.3. Academic performance of highly engaged students across varying behavioural patterns for Group B_1 semester 1.

High engagement		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_1	6	98.33	4.082	68.25	7.47	55.26	4.00
BP_2	41	96.34	13.87	61.00	19.63	50.69	12.41
BP_3	31	94.74	10.45	63.55	19.97	52.30	12.54
BP_4	9	89.89	10.13	53.67	13.60	51.05	8.17

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_1 = Q, BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

Table N.4. Academic performance of low engaged students across varying behavioural patterns for Group B_1 semester 2.

Low engagement		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_2	35	71.38	12.34	73.81	25.14	57.51	13.86
BP_3	2	78.33	2.36	21.00	3.54	30.01	2.17
BP_4	1	70.00	-	80.88	-	61.38	-

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

Table N.5. Academic performance of moderately engaged students across varying behavioural patterns for Group B_1 semester 2.

Moderate engagement		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_2	91	82.61	16.83	64.09	24.75	51.41	14.82
BP_3	8	80.71	23.77	66.61	29.32	51.61	17.18
BP_4	2	68.50	4.95	72.13	19.27	53.52	10.62
BP_6	2	16.66	9.43	62.88	14.50	39.85	9.20

Note. M = mean, SD = standard deviation, BP = behaviour pattern where $BP_2 = Q > V$, $BP_3 = Q = V$, $BP_4 = Q < V$, BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

Table N.6. Academic performance of highly engaged students across varying behavioural patterns for Group B_1 semester 2.

High engagement		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_2	31	70.11	12.16	70.90	27.22	55.94	14.92
BP_3	2	90.00	0	80.44	12.64	61.74	7.52
BP_4	1	80.00	-	88.44	-	65.77	-
BP_6	3	73.33	3.33	81.13	39.59	51.01	20.49

Note. M = mean, SD = standard deviation, BP = behaviour pattern where $BP_2 = Q > V$, $BP_3 = Q = V$, $BP_4 = Q < V$, BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

Table N.7. Academic performance of low engaged students across varying behavioural patterns for Group B_2 semester 1.

Overall pre-learning quiz				Tukey's HSD Comparisons			
	n	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	5	90.00	10.00	-			
BP_2	49	84.59	13.02	$p = 0.895$	-		
BP_3	7	60.71	4.50	$p = 0.002$*	$p < 0.001$***	-	
BP_4	2	55.00	7.07	$p = 0.013$*	$p = 0.016$*	$p = 0.981$	-
BP_6	19	30.26	14.58	$p < 0.001$***	$p < 0.001$***	$p < 0.001$***	$p = 0.079$
End of semester examination				Tukey's HSD Comparisons			
	n	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	5	57.15	23.41	-			
BP_2	49	52.59	20.33	$p = 0.991$	-		
BP_3	7	54.00	11.97	$p = 0.999$	$p = 1.000$	-	
BP_4	2	56.23	37.06	$p = 1.000$	$p = 0.999$	$p = 1.000$	-
BP_6	19	65.49	24.60	$p = 0.937$	$p = 0.178$	$p = 0.742$	$p = 0.977$
Overall course performance				Tukey's HSD Comparisons			
	n	M	SD	BP_1	BP_2	BP_3	BP_4
BP_1	5	47.74	13.76	-			
BP_2	49	44.61	12.49	$p = 0.990$	-		
BP_3	7	42.34	7.41	$p = 0.965$	$p = 0.995$	-	
BP_4	2	44.74	28.13	$p = 0.999$	$p = 1.000$	$p = 1.000$	-
BP_6	19	50.07	18.15	$p = 0.997$	$p = 0.608$	$p = 0.728$	$p = 0.986$

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_1 = Q, BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access, $^{**}p < 0.01$ $^{***}p < 0.001$.

Table N.8. Academic performance of moderately and highly engaged students across varying behavioural patterns for Group B_2 semester 1.

Moderate engagement		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_1	1	100	-	94.89	-	71.34	-
BP_2	69	94.57	12.16	60.10	20.16	49.55	12.36
BP_3	8	81.25	17.47	67.73	18.56	52.96	11.97
BP_4	1	50	-	52.42	-	41.16	-

High engagement		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_1	1	100	-	91.39	-	67.66	-
BP_2	51	98.43	4.64	67.61	16.74	54.59	10.36
BP_3	21	90.24	10.30	73.76	17.77	57.61	11.44
BP_4	1	100	-	88.95	-	67.92	-

Note. M = mean, SD = standard deviation, BP = behaviour pattern where $BP_2 = Q > V$, $BP_3 = Q = V$, $BP_4 = Q < V$, BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access.

Table N.9. Academic performance of all engagement groups for students across varying behavioural patterns for Group B_2 semester 2.

Low engagement		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_2	36	88.47	11.16	52.57	20.69	44.29	12.69
BP_3	1	58.00	-	78.00	-	58.70	-
BP_4	4	46.25	5.85	35.25	13.86	30.10	7.94
BP_6	19	50.47	33.38	63.91	26.15	42.12	23.43

Moderate engagement		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_2	57	90.91	11.16	53.50	17.61	45.119	10.88
BP_3	2	49.50	33.23	44.00	47.38	32.81	29.91
BP_4	1	42.00	-	36.00	-	24.00	-
			-				

High engagement		Pre-learning quiz		End of semester examination		Overall course performance	
	n	M	SD	M	SD	M	SD
BP_2	39	96.63	4.95	64.76	18.86	50.81	13.66
BP_3	11	86.27	11.76	73.41	16.24	56.29	11.03
BP_4	4	80.25	12.39	70.83	4.62	43.41	20.07

Note. M = mean, SD = standard deviation, BP = behaviour pattern where BP_1 = Q, BP_2 = Q > V, BP_3 = Q = V, BP_4 = Q < V, BP_6 = N/A, where Q represents frequency of pre-learning quiz access and V represents frequency of pre-learning video access, $**p < 0.01***p < 0.001$.