Achieving What Gets Measured: Responsive and Reflective Learning Approaches and Strategies of First-Year Engineering Students

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Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of
Doctor of Philosophy
in
Engineering Education

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December 20, 2021
Blacksburg, VA

Keywords: Engineering, Learning Strategies, Reflection, First Year

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ABSTRACT

Background: Engineering students who achieve academic success during their first year may later disengage from challenging course material in their upper-level courses, due to perceived differences between their expectations and values and those of their degree programs. In the extreme, academic disengagement can lead to attrition.

Purpose: The purpose of this study is to better understand the learning approaches and strategies used by first-year engineering students. Research questions were as follows:

- How do first-year engineering students describe their learning approaches and strategies?
- How do first-year engineering students customize their learning strategies among their courses?
- How do first-year engineering students employ reflection as part of their learning strategies?

Design/Method: I employed both qualitative and quantitative methods to collect and analyze data, using an explanatory design approach consisting of two surveys and a set of semi-structured interviews between survey administrations. The interview data from a purposive sample of survey participants were coded using a priori, pattern and comparative coding.

The survey data were analyzed for medians and interquartile ranges in order to identify trends in reflective learning strategies among courses.

Results: One notable finding was the fact that many interviewees stated that their overall purpose for studying was to achieve high grades by preparing for tests (a surface-level approach), and yet the learning strategies that they used reflected a deeper engagement with their course material than one would expect from students whose singular focus was on grades. Certain strategies were similar for both technical and non-technical courses, while others were dissimilar. There are also ways to combine the surface and deep learning strategies sequentially. They need not be mutually exclusive.

Conclusions: The results of this study will provide educators with a starting point for the development of guided practice in meaningful learning strategies to encourage a greater engagement with learning. Both educators and administrators should be amenable to measures that would improve their students' chances for success, by providing guidance in how to learn as well as what to learn. Several recommendations are given for future studies, such as the relationships among reflection, metacognition, and critical thinking, and the integration of meaningful learning strategies into technically overloaded engineering degree curricula.

ABSTRACT FOR A GENERAL AUDIENCE

Natalie Christine Trehubets Van Tyne

I chose to study the learning approaches and strategies of first-year engineering students. The term "learning strategies" refers to study habits, but learning strategies also involve choices about how to study based on goals, motivation, and available resources. My results will provide professors and instructors with insights that they can use to help their students learn more effectively and find deeper meaning in their course material, by guiding them in how to learn as well as what to learn. Knowing how to learn is a lifelong skill. First-year engineering students have a special need to know how to learn in order to be better prepared for a more challenging workload in their upper level engineering courses. Prior studies have shown that students most often leave an engineering program during their first or second year due to inadequate academic preparation in prior years. If we are to help engineering these students to improve their learning approaches and strategies, we first need to know what approaches and strategies they currently use.

My data came from two surveys that were given at the end of each of two introductory engineering courses to a group of approximately 1,200 students, and from interviews with fifteen students who had also completed the surveys. I was trying to learn more about how these students customized their learning strategies among their courses, and how they used reflection to discover the meaning behind what they are learning. One of the most interesting findings was the fact that many interviewees stated that their overall purpose for studying was to achieve high grades by preparing for tests (a surface-level approach), and yet the learning strategies that they used reflected a deeper engagement with their course material than one would expect from students whose only focus was on grades. This combination of different learning approaches was more common in engineering, science and mathematics courses than in humanities or social science courses.

This dissertation also contains a three-part class assignment, given at the beginning, middle, and end of a first-year engineering course, in which students reflect on their progress in learning one or more skills that they had identified at the beginning of the course. Implications arising from my study are directed at researchers, administrators, faculty, and students, respectively, as well as opportunities for further work in this aspect of higher education. Opportunities for further studies include the relationship between reflection and critical thinking, and methods for incorporating guided practice in learning strategies into engineering degree programs that currently contain too much technical content.

Acknowledgements

To my advisor, Dr. Lisa McNair, thank you for your endless patience as I learned how to become an educational researcher. I am sure that my tendency to be long-winded must have been trying at times. You have been generous with your time and attention, and readily flexible when dealing with a non-traditional graduate student.

To my committee members, Drs. David Knight, Rachel Ellestad, and Michelle Soledad, thank you for providing out-of-the-box thinking and insights without reservation, which helped me to grow as a researcher-educator. You have given me a lot of technical support and guidance, for which I am grateful.

To my family: Chester; Mary and Joe; Daria, Jonathan, Albie, Isaiah, and Josie; Kasey, Steve, and Eddie; Fiona and Julian; and extended family members, thank you for all that you do and all of the ways that you show your love and support for my endeavors. I am proud to be associated with you.

To Dr. Jennifer Case, head of the Department of Engineering Education, and former heads Drs. Donna Riley and Stephanie Adams, thank you for your support and for the resources to enable me to complete this program while teaching full time. I hope to continue to put research into practice using new discoveries and insights for the benefit of our students.

To the faculty and staff in the Department of Engineering Education, thank you for your fellowship and encouragement in helping me to feel welcome and to belong here. I am happy to be a part of our department.

This dissertation is based on research conducted under the auspices of the Department of Engineering Education, College of Engineering, Virginia Polytechnic Institute and State University, where its results are intended for the benefit of first-year engineering students.

Dedication

This work is dedicated to my husband, Chester Van Tyne. I could not have completed this program without his love, support and sacrifice, especially during these last 6-1/2 years.

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1.0 Introduction

In my nineteen years of teaching first-year engineering courses, I have observed numerous instances of students' tendencies to work on homework assignments and study for tests at the last minute, "just-in-time" to meet a deadline. While "just-in-time" processes may work well in manufacturing or when handling fresh foods, the habit of attempting to learn at the last minute often results in poor-quality work and poor performance on tests, and may also cause students to wonder what they actually learned when they consider their course experiences at a later time. These habits become even more disadvantageous to engineering students when they encounter upper-level courses with greater academic challenges, and may cause them to disengage rather than adjust to these heightened expectations. The underlying reason for this disengagement lies with their expectations for academic success, which could be incompatible with the second-year expectations of their chosen disciplines and institutions (Brint & Cantwell, 2014; Schreiner, Slavin Miller, Pullins & Seppelt, 2012).

The purpose of this study is to better understand the learning approaches and strategies used by first-year engineering students in order to inform appropriate interventions to mitigate academic disengagement in later years. Therefore, the results of this study will provide educators with a starting point for the development of guided practice in meaningful learning strategies to encourage greater engagement with learning. Greater engagement, in this context, means that students think more deeply about what they are learning, what it means, and the ways in which the seemingly different bodies of knowledge in their course loads are interrelated.

By neglecting to set priorities, monitor progress, and search for the underlying meaning of their course material, college students may do well enough to "get by" and achieve success during their first year—and yet fail to continue to succeed when they encounter greater academic rigor in their upper-level courses (Kennedy & Upcraft, 2010; Nilson, 2016; Schreiner & Tobolowsky, 2018). This is especially true in technical disciplines (Seymour & Hewitt, 1997). As a result, they may choose to disengage from studying rather than apply approaches and strategies for learning that would enable them to be more successful (Nilson, 2016; Schaller, 2010; Schreiner, et al., 2012). Therefore, a better understanding of the existing learning approaches and strategies that these students use is a necessary starting point for the mitigation of possible academic disengagement in later academic years.

This chapter provides an overview of the purpose and context for this study, the underlying problem that the study results may help to address, an overall study plan, examples of learning approaches and strategies, the major contributions of this study, stakeholder interests, and study limitations. My principal conceptual framework for this study consists of Biggs' approaches to learning, which is underscored by Flavell's theory of metacognition as a self-directed aspect of learning (Biggs, 1988, 1996; Biggs & Tang, 2011; Flavell, 1979). Kember's four-stage model for reflection will also be included in my chosen conceptual framework to characterize reflective learning strategies (Kember et al., 2008; Kember & Ginns, 2012; Leung & Kember, 2003). These frameworks are based on the constructivist worldview, in which knowledge is constructed by the learner rather than derived from an all-knowing authority (Baxter-Magolda, 2004).

My study will employ both qualitative and quantitative methods to collect and analyze data, using an explanatory sequential design (Creswell & Plano Clark, 2011). The data are expected to reveal the existing learning approaches and strategies used by first-year engineering students, which can inform the development of guided practice toward greater engagement with learning. The enhancement of academic engagement in the first year has been shown to increase the probability of academic success in the succeeding years of an undergraduate engineering degree program (Downing, 2009; Prince, 2004; Seymour & Hewitt, 1997).

1.1 Definitions

Based on the frameworks indicated above, I will define the following terms to provide the context for this study:

Academic disengagement is the incompatibility between students' expectations, values, and expected behaviors for academic success and the expectations, values, and modeled behaviors of the institution (Brint & Cantwell, 2014). It can be manifested in a lack of interest in studying, skipping classes, and a failure to form the self-regulating behaviors necessary for intellectual and skill development, to name a few examples (Brint & Cantwell, 2014).

Approaches to learning are the overarching methods, including cognitive and metacognitive strategies, that students apply to their learning (Biggs, 1988, 1999; Felder & Brent, 2005; Floyd, Harrington & Santiago, 2009; Leung & Kember, 2003). Three major approaches to learning are:

- <u>Surface Learning</u>: a learning approach influenced by extrinsic motivation to meet external requirements to the minimum extent permissible;
- <u>Deep Learning</u>: a learning approach influenced by intrinsic motivation, prompting the student to understand the study material thoroughly and seek more knowledge about it; and
- <u>Achieving Learning</u>: a learning approach that may be extrinsically or intrinsically motivated, where the primary goal is achieving a high grade through either a surface or a deep approach, depending on priorities and context.

Learning strategies are behaviors that students use for studying and learning course material, such as memorizing, re-writing course notes, planning and organizing materials, questioning self and others, and reflection (Crede & Kuncel, 2008; Hartwig & Dunlosky, 2012; Karpicke, Butler & Roediger, 2009). The extent to which these strategies and others are employed is driven by a student's approach to learning and are often used in response to external demands for performance.

Metacognition is literally "cognition about cognitive phenomena" or "thinking about thinking" (Flavell, 1979). A commonly recognized theory of metacognition contains concepts of metacognitive knowledge and metacognitive experiences or strategies (Flavell, 1979). In my study, metacognitive knowledge relates to the choice of a learning approach, while metacognitive strategies tend to be self-regulating, such as self-questioning, self-monitoring, self-testing, and self-evaluation, any of which may also involve reflection.

First-year engineering students in my study are students enrolled in introductory engineering courses, with the intent to major in an engineering discipline.

Reflection is a careful, continuous examination of knowledge and beliefs in view of supporting evidence (Leung & Kember, 2003). It is also a form of mental processing that can be directed at a specific outcome or used to ponder a question or problem that does not have an obvious solution (Moon, 2007). When applied to learning approaches and strategies, reflection can be useful in reviewing, interpreting, and understanding encounters with knowledge as insights into future behaviors and actions (Wald, Borkan, Taylor, Anthony & Reids, 2012).

Technical courses include college-level engineering, physical science, mathematics, and related interdisciplinary courses.

Physical Science courses include physics, chemistry, biology, earth sciences, astronomy, computer science and related interdisciplinary courses.

Non-Technical courses include social science and humanities courses, such as English, history, psychology, sociology, economics, the arts, and foreign languages.

ENGE is the abbreviation for the Virginia Tech Department of Engineering Education and is used as the prefix for courses delivered by that department.

Responsive learning strategies are those strategies that are applied with a specific end goal in mind, such as understanding a concept or solving prospective test problems.

Reflective learning strategies are those strategies that prompt for additional exploration into course material in order to discover and use the deeper meaning that is there, but is not always obvious.

1.2 Statement of the Problem

Academic disengagement in either the first or second year of an engineering program has been a major reason for attrition from engineering and other academic programs (Chen & Soldner, 2013; Cherif, Adams, Movahedzadeh, Martyn & Dunning, 2014; Cherif, Adams, Movahedzadeh & Martyn, 2015; Eris, Chachra, Chen, Sheppard, Ludlow, Rosca…& Toye , 2010). Approximately 40% of all students who enter an engineering program will leave it before they graduate (Chen & Soldner, 2013; Ohland, Sheppard, Lichtenstein, Eris, Chachra & Layton, 2008). Academic disengagement based on lack of preparation is a major reason for leaving, which indicates that increased attention to learning approaches and strategies during the first year is appropriate (Chen & Soldner, 2013; Ohland et al., 2008; Seymour & Hewitt, 1997).

Academic disengagement tends to arise from a fundamental incompatibility between students' expectations and values and those of the institution (Brint & Cantwell, 2014).

Students will choose a particular learning approach and its strategies in accordance with their expectations and values (Biggs, 1988; Cherif, Movahedzadeh, Adams & Dunning, 2013; Jones, 2009, 2018). Following this line of reasoning, if students placed more value on learning through the adoption of meaningful learning approaches and strategies, they would be less likely to disengage from academics because their values and expectations would become more closely aligned with those underlying the demand for increased academic rigor during the sophomore year and beyond.

A strong first-year academic performance, driven by academic engagement and strategies for meaningful learning, could mitigate the likelihood of attrition (Gore, 2006). Moreover, the first year of college is an ideal time to promote more effective and meaningful approaches and strategies because their benefits can be realized earlier and more often (Downing, 2009).

While numerous prior studies in learning approaches and strategies have been conducted with undergraduate students pursuing a variety of engineering and non-engineering degree programs, my review of the literature found only one study involving first-year engineering students (Meyer, Knight, Baldock, Kizil, O'Moore & Callaghan, 2012). Other studies involved undergraduate students in which the class year was not specified (Biggs, 1988; Biggs, Kember & Leung, 2001; Crede & Kuncel, 2008; Hartwig & Dunlosky, 2012; Karpicke et al., 2009; Kornell & Son, 2009; McCord & Matusovich, 2013; Meyer et al., 2012; Morehead, Rhodes & DeLozier, 2016).

Because the existing learning approaches and strategies used by first-year engineering students may not prepare them to meet the increased academic rigor often encountered during their sophomore year, resulting in poor academic performance in upper level courses, these students may disengage from academics. To address this problem area, my study examines the existing learning approaches and strategies used by first-year engineering students. Moreover, I elevate reflection as a particularly useful learning strategy for mitigating academic disengagement because it generates a deeper meaning in what is learned, promotes relevance to a student's existing body of knowledge, and increases the probability that an item of knowledge will be retained for longer-term retention and transfer.

1.3 The Purpose of This Study

The purpose of this study is to explore and analyze the learning approaches and strategies currently used by first-year students who intend to pursue an undergraduate bachelor's degree program in their chosen engineering discipline. The results of this study will provide educators with a starting point for the development of interventions to encourage greater academic preparation and engagement with learning.

Unlike prior studies in which participants indicated their learning approaches and strategies across all of their courses, my study will involve the differentiation in the use of learning approaches and strategies among courses in order to reveal and explore the reasons for the application of different approaches and strategies in different courses. Since technical courses and non-technical courses often have different types of learning outcomes, it is reasonable to expect that students would apply different learning strategies, as necessary, to meet the requirements of their courses.

1.3.1 Research Questions

A thorough characterization of learning approaches and strategies among first-year engineering students is a necessary first step toward the introduction and practice of meaningful learning strategies to mitigate current and future academic disengagement in undergraduate engineering programs. Therefore, my research question is as follows:

- How do first-year engineering students describe their learning approaches and strategies?

This question is accompanied by these two sub-questions:

- How do first-year engineering students customize their learning strategies among their courses?
- How do first-year engineering students employ reflection as part of their learning strategies?

Learning strategies are behaviors that students use with the belief that these strategies will help them to improve their academic performance. These behaviors enable students to exercise some measure of control, and therefore empowerment, over the unfamiliar academic structures and challenges that they will encounter as sophomores. Therefore, effective learning strategies can be a highly influential method for overcoming academic disengagement.

1.3.2 Examples of Learning Strategies

A variety of learning strategies have been reported in the literature. These strategies have been applied across disciplines and are either extrinsically or intrinsically motivated. A selection of learning strategies is given in Table 1.1 on the next page:

Table 1.1: Examples of Learning Strategies

Learning Strategy	Type of Motivation	Source(s)
Memorizing information	Extrinsic	(Karpicke, et al., 2009; McCord & Matusovich, 2013)
Reviewing/outlining course notes and/or textbook chapters before a test	Extrinsic	(Crede & Kuncel, 2008; Hartwig & Dunlosky, 2012; Karpicke et al., 2009; Morehead, et al., 2016)
Re-working homework or other practice problems	Extrinsic	(Hartwig & Dunlosky, 2012; Morehead et al., 2016)
Rewriting notes from lectures or readings	Extrinsic	(Karpicke et al., 2009)
Using flashcards or mnemonics (e.g., acronyms or rhymes)	Extrinsic	(Karpicke et al., 2009)
Studying with a group of students	Either extrinsic or intrinsic	(Karpicke et al., 2009)
Setting priorities for what to study next	Intrinsic	(Crede & Kuncel, 2008; Hartwig & Dunlosky, 2012; Morehead et al., 2016)
Organizing, summarizing, and integrating course material	Intrinsic	(Crede & Kuncel, 2008)
Self-questioning or self-testing	Intrinsic	(Crede & Kuncel, 2008; Hartwig & Dunlosky, 2012; Karpicke et al., 2009; Morehead et al., 2016)
Relating material to real-life examples through reflection	Intrinsic	(Karpicke et al., 2009)
Questioning others, such as an instructor or other students	Intrinsic	(Hartwig & Dunlosky, 2012; Karpicke et al., 2009; McCord & Matusovich, 2013; Morehead et al., 2016)

The first five learning strategies are mainly concerned with recalling information from memory, often performed in preparation for tests, using only the material provided by the instructor, and are extrinsically motivated because they are performed in response to demands imposed by educators (Ryan & Deci, 2000). The last five strategies are intrinsically motivated, because students who use these strategies are more aware of what they are studying, how they should study it, how various components of the material fit together, and the intrinsic value of the material to the student. What also makes these strategies intrinsically motivating is that the student may augment their knowledge using resources outside of the course. The strategy of studying with a group can be either extrinsically or intrinsically motivated, depending on how the students use their time and other resources during group study.

Any of the intrinsically motivated strategies listed in Table 1.1 may also involve reflection to promote self-awareness, the emergence of deep understanding, and the recognition of relationships among course components, all of which may result in meaningful learning. However, I have found relatively little evidence to date about the specific ways in which reflection enhances the value of learning strategies beyond a passing mention of its existence in the processes of learning. This gap in knowledge provides evidence for the importance of my second research sub-question.

1.3.3 The Value of Reflective Learning Strategies

Reflection can be an enhancement to learning strategies because it is an analysis of past or current events to reveal patterns in and relationships among knowledge that combine into useful mental models for understanding and resolving real-world issues and problems. For students in particular, reflection can help students to refine their prior knowledge and improve metacognition as they reflect on how and why they think about and approach their work in certain ways.

A number of investigators have explored the role of reflective learning strategies, such as self-questioning and questioning others, as shown in Table 1.2 on the next page:

Table 1.2: Applications of Reflective Learning Strategies

Reflective Learning Strategy	Source(s)
Recognizing the difference between beliefs about knowledge as absolute vs. contextual	(King & Kitchener, 1994; Perry, 1999)
Attaining an intense level of understanding that leads to a transformation of one's perspective	(Kember, et al., 2008)
Employing metacognition to examine one's learning process and how new knowledge influences prior knowledge	(Chabon & Lee-Wilkerson, 2006)
Accepting the perspectives of others as valid and examining them critically	(Hatton & Smith, 1995; Moon, 2004; Sparks-Langer, Simmons, Pasch, Colton & Starko, 1990)

1.3.4 Overall Research Plan

Table 1.3, on the next page, indicates how these research questions were addressed through data collection and analysis, along with the implications of the results. Two surveys were administered to collect data about the frequency of responsive and reflective learning approaches and strategies from two study samples, each consisting of approximately 1,200 participants. These data were then analyzed using descriptive statistics. A purposive, stratified sample of 15 participants was selected from the first study sample. These participants were interviewed to collect additional data about their learning approaches and strategies. The interview transcripts were analyzed by coding for the identification of learning approaches and strategies used in both technical and non-technical courses, and as examples of the use of reflective learning strategies.

Table 1.3: Overall Research Plan and Anticipated Results

Research Question	Data Collection Methods	Data Analysis Methods	Anticipated Results
How do first-year engineering students describe their learning approaches and strategies among their courses?	11 questions added to a department's end of semester survey in Fall 2020 and Spring 2021, respectively (**Study Samples**)	Summarize results within and among four types of courses for both **Study Samples**, including median Likert scores and reconciliation to the Likert scale methodology. Describe general agreement or disagreement among members of the **Study Samples** and **Interviewee** groups, based on quartiles and Interquartile Range values.	Quantitative profiles of **Study Samples'** learning approaches and strategies, including common and diverse strategies within and among courses, including indications of the use of reflective learning strategies
	15 semi-structured interviews, each containing 7 standard questions and several follow-on questions (**Interviewees**)	*a priori*, pattern, and comparative coding of **Interviewees'** transcripts	Qualitative and rich descriptions of **Interviewees**' learning approaches and strategies within and among courses, including the use of reflective learning strategies.

1.3.5 Alignment Among the Research Question, Conceptual Framework, Research Methods, and Results

My overall framework for alignment is shown in Section 3.6.1, in which I described the relationships among the research question, conceptual frameworks, and choices of research methods. The results were made possible through my data collection and analysis methods, which were informed and modified from similar instruments methods used by these two researchers, i.e, Biggs Study Processes Questionnaire and Kember's Reflection Questionnaire, respectively (Biggs et al., 2001; Kember, Leung, Loke, McKay, Sinclair, Tse, Webb, …&Leung, 2000, Kember, et al.,2008). These methods are described in Chapter 3. These instruments, along with similar surveys and questionnaires described in Chapter 2, also informed the development of the interview questions that produced highly detailed information about the learning approaches and strategies of the Interviewees.

My results provided the answers to the research question and its sub-questions through the collection of both survey and interview data. The combination of analysis methods that I chose also provided more extensive information than one survey or one set of interviews would have provided, as well as the opportunity to triangulate the interview data with the survey data for the same group of participants to provide validation. The types of coding described in Chapter 3 provided not only the identification of learning strategies, but their relationship to learning approaches, variations in the use of these strategies among courses, and specific examples of the use of reflective learning strategies.

1.4 Study Context

My research questions will be addressed by exploring the learning approaches and strategies of first-year engineering students enrolled in introductory engineering courses at a research-based university in the eastern United States. The identification of current learning approaches and strategies will produce indicators of potential academic disengagement during the sophomore year, as the academic workload becomes more rigorous than these students might expect, based on their introduction to engineering on the college level.

1.4.1 Description of the Study Samples and Purposive Sample

An end of-semester survey was administered to approximately 2,000 first-year engineering students enrolled in sections of two introductory engineering courses: ENGE 1215 and ENGE 1216, during the fall and spring semesters, respectively. Two **Study Samples**, each consisting of approximately 1,200 participants, emerged from the study population based on their consent to participate in this and similar research studies. The purposive sample of **Interviewees** was selected from approximately 260 **Study Sample, Fall 2020** participants who had volunteered for interviews (**Interview Volunteers**).

Interviewees were invited in proportion to the gender demographics of the study sample, with approximately equal numbers of participants whose survey results indicated that they might have an overall surface, deep or achieving learning approach, which would influence their choices of learning strategies.

1.5 Significance of This Study

Since there is currently a lack of sufficient knowledge about the learning approaches and strategies of first-year engineering students, and the ways in which these approaches and strategies might vary among their courses, the results of this study provided a clear and definitive profile of which approaches and strategies are used among the members of these two Study Samples. In addition, engineering students take a variety of both technical and non-technical courses, in which the differences in the use of reflection between these two types of courses have not yet been explored. Identification of the use of reflective learning strategies in both technical and non-technical courses would therefore provide a worthwhile contribution to the body of research about the study of teaching and learning.

Finally, the baseline knowledge of how first-year engineering students currently employ learning approaches and strategies provides a starting point for appropriate guided practice in teaching and learning interventions to promote more informed choices among these approaches and strategies. First-year engineering students need to recognize, accept, and internalize the benefits of “deep” and meaningful learning approaches and strategies to improve their academic preparation for the challenges of discipline-specific engineering courses in later years.

1.6 Stakeholder Interests

The needs and interests of a variety of stakeholders, including first-year engineering students, engineering faculty, educational researchers, and society at large, will be addressed through improvements in learning strategies emerging from the results of this study. This section contains the rationale for meeting the needs and interests of these groups of stakeholders.

1.6.1 First-Year Engineering Students

Many first-year engineering students need more meaningful learning approaches and strategies to bolster their academic self-concept, self-efficacy, and sense of competence in order to persist in an academic, e.g., engineering program (Bong & Skaalvik, 2003; Deci & Ryan, 2000; Kennedy & Upcraft, 2010). Better learning strategies can also lead to higher grades, which students value as proof of their competence for their chosen career (Kennedy & Upcraft, 2010; Schreiner et al., 2012).

1.6.2 Engineering Faculty

The results from this study will inform educators as to how to guide their students toward more meaningful learning strategies for greater academic success during and beyond the first year (Allen, Robbins, Casillas & Oh, 2008; Downing, 2009; Gore, 2006; Litzinger, Lattuca, Hadgraft & Newstetter, 2011; Robbins, Lauver, Le, Davis, Langley & Carlstrom, 2004). The determination of what learning approaches and strategies are currently in use provides a baseline for relevant guided practice.

Guided practice in those learning strategies that are intended to increase knowledge retention and transfer to upper-level courses and beyond would then be formed using a constructive alignment method, according to Biggs (1996, 2003). Both first-year and upperclass faculty assume that their students have retained knowledge and skills from prerequisite courses or admissions requirements that can be instantly used in their own courses, which has been disproven (Cherif, et al., 2014). Adoption of more effective and meaningful learning strategies during the first year increases the probability that prior knowledge will be retained for use in upper-level courses.

1.6.3 Educational Researchers

The revelation of learning strategies used by first-year engineering students provides missing pieces in the study of student learning that should be of interest to researchers at the first-year level (ASEE, 2009). The results of this study will inform practice at multiple stages of learning, but it will first reveal how first-year engineering students currently practice learning strategies, which is a largely underexplored area of study.

The adaptation of the Kember Reflection Questionnaire to accommodate different responses for different courses provides the opportunity for differences in the use of reflection among courses in a first-year engineering curriculum, which is a hitherto unexplored area, and therefore would be of interest to researchers who study the use of reflection in learning, as well as those who conduct research involving first-year engineering students.

1.6.4 Society at Large

Learning approaches and strategies are also transferrable to the world at large because students who learn more effectively and meaningfully will be better able to resolve complex societal problems for the benefit of all citizens. Among meaningful learning strategies, reflection is especially useful for identifying, analyzing, and resolving ill-structured problems that may arise from conflicting values, motives, and incentives.

1.7 Limitations and Biases

This study is limited to a defined population of first-year engineering students at a single, large, research-based institution located in a single geographic region, during two semester-long study periods. In addition, participation in this study was limited by consent to release survey results for research purposes. For this reason, all findings will be reported with close attention to their context.

Interviews, no matter how carefully conducted, were limited by the time available to interact with participants, particularly since the interviews were conducted online. Participants were assumed to respond truthfully when completing surveys and interviews, but response bias was possible, due to my dual role as an instructor and as a researcher. I conducted interviews with only those participants whom I was not instructing at the time of the interview. However, considering my dual role as both a researcher and an instructor, it was possible that interview participants were reluctant to reveal that they used a superficial or "surface" approach to studying because of social desirability bias. This bias was mitigated by the intent of my interview questions and using techniques of phenomenographic interviewing by asking questions and prompting responses in a non-judgmental manner.

Researcher bias was also possible, although it was mitigated by adherence to the constructivist worldview, which justified the co-creation of knowledge by researcher and participant. Since I also held strong positive views about the value of reflection to student learning, I sought to avoid unnecessarily injecting the concept of reflection into my interview prompts, in order to avoid compromising an otherwise genuine response.

1.8 Chapter Summary

This chapter introduced my study to explore and analyze the existing learning approaches and strategies of first-year engineering students, with the underlying intent to mitigate potential academic disengagement in succeeding years due to poor academic preparation and lack of engagement with meaningful learning approaches and strategies. While faculty may not be able to control, prevent, or mitigate all of the causes of academic disengagement, more can be done to provide guided practice in constructive learning approaches and meaningful learning strategies once the specific needs of first-year engineering students for the enhancement of both of these aspects of learning have been identified.

2.0 Review of Literature

2.1 Introduction

The focus of my study was to explore the responsive and reflective learning approaches and strategies currently used by first-year engineering students among their courses in order to detect indicators and causes of academic disengagement. This form of disengagement can lead to poor preparation for the rigors of an engineering curriculum in the sophomore year and beyond, when the demand to assimilate and implement conceptual knowledge dramatically increases (Litzinger et al., 2011; Seymour & Hewitt, 1997). However, it has been reported that many students are ill-equipped to meet this challenge (Geisinger & Raman, 2013; Litzinger et al., 2011; Prince & Felder, 2006). Therefore, this literature review will answer the following questions:

- What are the short-term and long-term consequences and implications of academic disengagement?
- What responsive and reflective learning approaches and strategies have been identified as effective for mitigating academic disengagement among undergraduate students?

The current learning approaches and strategies of first-year engineering students have been largely underexplored in the literature. In addition, the studies in this review identified learning approaches and strategies that students used without respect to how these might vary among individual courses. Therefore, two major contributions of my study to the body of knowledge about learning approaches and strategies will be:

- Identification of the learning approaches and strategies used by first-year engineering students, and
- How the use of these learning approaches and strategies varied among the types of courses in a first-year engineering curriculum.

This chapter begins with a review of the impacts of academic disengagement on college students and why engineering students are no less susceptible to it. If left unchecked, academic disengagement can lead to attrition from engineering and other programs, which might have been prevented if recognized and addressed during the first year of college, when the benefits of greater academic engagement can be realized earlier and more often (Downing, 2009).

Because the premise for my study is that meaningful learning approaches and strategies can be used to mitigate academic disengagement, the middle sections of this chapter provide background information about the most common learning approaches and strategies in use among engineering and other college students, and the rationale for these approaches and strategies.

Since reflection has been shown to provide valuable insights into learning, the influence of reflective learning strategies is explored in the latter sections, including conceptual models and specific examples of how reflection reinforces self-regulating and metacognitive learning strategies. The benefits of reflection for knowledge transfer and retrieval are also included, as well as the impact of beliefs about knowledge on learning strategies, as revealed through reflection. Finally, a review of the most common research methods for exploring these approaches and strategies is also provided, including methods to characterize reflection, in order to inform the research plan for my study.

Both quantitative and qualitative methods have been used in the present work, although quantitative methods, such as surveys and statistical analysis, were prevalent in this set of representative studies. However, in a few cases, interviews and coding were used to inform the formation of surveys. In my research plan, the quantitative results will corroborate or refute the results of coded interview data, as well as to provide evidence of the validity and reliability of the data collection instruments.

2.2 Impacts and Consequences of Academic Disengagement

Academic disengagement can be attributed to an incompatibility between students' expectations and values and those of the institution (Brint & Cantwell, 2014). Examples of academic disengagement include poor academic performance, social isolation, apathy toward studies and the institution, and showing effort below a student's capabilities (Ohland et al., 2008; Schaller, 2010). These behaviors, in turn, have been shown to result in feelings of isolation, apathy, confusion, and disillusionment, which can lead to further disengagement and, in the extreme, attrition (Baldwin & Koh, 2012; Brint & Cantwell, 2014; Graunke & Woosley, 2005; Sterling, 2018; Tinto, 2017).

Students may experience academic disengagement as a lack of integration with the institution if they are receiving poor grades as an indicator of poor intellectual development, which contradicts the main purpose for attending a college or university (Brint & Cantwell, 2014; Graunke & Woosley, 2005). These impressions may also affect a student's sense of competence for their chosen career (Brint & Cantwell, 2014; Graunke & Woosley, 2005; Schreiner et al., 2012). Academic disengagement may also emerge from students' assumption that choosing a particular major precludes alternative career options, such as careers that they do not recognize as arising from that major (Gore & Hunter, 2010), and therefore think they are "locked in" for life, without the ability to change from one career to another (Schreiner, 2010).

2.2.1 Motivational Factors for Academic Disengagement

The roles of values and motives in determining the choices of learning approaches and strategies can be explained by the theoretical models for self-efficacy (Bandura, 1977b) and self-determination (Deci & Ryan, 2000). Past academic success can serve as a motivator for future success under the self-efficacy theory, and a sense of competence based on successful academic performance can motivate a student to continue trying when a topic is difficult to understand or master, according to the theory of self-determination (Deci & Ryan, 2000).

Poor academic performance can also lead to a student's impression that they are less competent than they thought and perhaps not competent enough for their chosen major program or career path (Kennedy & Upcraft, 2010). A sense of competence can lead to empowerment over a chosen career path (Gore & Hunter, 2010; Jones, 2018). Empowerment sustains a student's sense of purpose, which provides additional motivation and leads to engagement with learning, as well as with other aspects of the college experience (Gardner, 2010).

A need for competence was recognized as one of three fundamental human needs by Deci and Ryan (2000), with the other two being autonomy and relatedness, as part of their application of self-determination theory to the development and pursuit of goals driven by intrinsic motivation. The authors emphasized that competence alone was not sufficient for intrinsic motivation but worked in concert with autonomy to promote it (Deci & Ryan, 2000). Moreover, competence may also be extrinsically motivated, such as the obligation to pass a course in order to meet the externally-imposed requirements of a degree program or to overcome obstacles to the attainment of a degree.

Deci and Ryan (2000) also related the need for competence to the reality of adaptation to new challenges in changing contexts resulting from the need to learn how to cope with everyday life, which may sometimes include learning to survive. As a result, people, including students, derive satisfaction from learning, as well as to fulfill a need for competence, because if they did not, they would not be able to respond to new situations or challenges that might be either advantageous or threatening (Deci & Ryan, 2000). When students are unable to satisfy their need for competence, they either adapt or disengage.

When class size, a contextual factor, increases, direct contact with faculty, which is often found to keep students engaged with their education, also becomes more difficult (Graunke & Woosley, 2005; Schreiner et al., 2012). Lack of contact with faculty may contribute to disengagement with higher education by disregarding students' need for relatedness and caring in order to maintain academic motivation and engagement with learning (Deci & Ryan, 2000; Jones, 2009, 2018). The concept of relatedness is based on aspects of self-determination theory, stating that not only do humans have a need to develop a strong sense of self, but also that the self has a need to integrate with other selves in a social structure (Deci & Ryan, 2000). This relates to college students when they regard their engagement with a course as engagement with a learning community that consists of fellow students and the instructor as major aspects of a learning environment. Disconnection from fellow students and/or the instructor can, therefore, contribute to academic disengagement.

Constructive contact with faculty demonstrates a component of Jones' MUSIC model of motivation known as "caring" (Jones, 2009), and contributes to academic engagement when the student recognizes that the instructor cares about their learning and is willing to help them with it. Helpful instructors also demonstrate caring for the student as a person (Jones, 2018). This contributes to self-esteem as well as academic self-concept, as described in Section 1.6.1 (Bong & Skaalvik, 2003). While the needs for relatedness (Deci & Ryan, 2000) and caring (Jones, 2009) could apply to all students, their role in promoting academic engagement seems to be acute for sophomores, according to Kennedy and Upcraft (2010), Schreiner (2010) and Schreiner and Tobolowsky (Schreiner & Tobolowsky, 2018).

2.2.2 How Academic Disengagement Affects Engineering Students

All of the causes of academic disengagement described in the aforementioned studies of general student populations were also found to apply to engineering students (Ohland et al., 2008). This conclusion was based on data collected from the National Survey of Student Engagement (NSSE), along with the Multiple Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) (Ohland et al., 2008).

The study population represented by the MIDFIELD database contained approximately 70,000 students among nine institutions, who had matriculated in either engineering, other technical and non-technical major programs, while the NSSE dataset was drawn from 73,000 first-year and senior students in 185 institutions (Ohland et al., 2008). A third source of data was made available from an additional longitudinal study of 160 students from four institutions; all of the data were combined to produce the findings for this study (Ohland et al., 2008).

2.2.2.1 Earlier and Concurrent Evidence of Academic Disengagement in Technical Programs

An earlier and equally extensive study of academic disengagement and attrition among students in technical majors, including engineering, revealed many of the same reasons for academic disengagement as those mentioned earlier for general college populations, such as poor academic preparation, incompatibility of values, dissatisfaction with the ways in which courses were taught, and perceptions of incompetence arising from poor grades and lack of integration with a chosen major's program (Seymour & Hewitt, 1997). This lack of integration, based on interest as well as on first-year academic performance, was further explored in two additional studies in 2008 (Allen et al., 2008; Allen & Robbins, 2008).

Allen and Robbins (2008) included engineering students as part of a study in persistence to degree completion involving 23 major programs among 25 four-year institutions. Their findings revealed that engineering students were among the most persistent of all major groups and emphasized that first-year GPA could be used as a predictor of persistence; i.e., the higher the first-year GPA, the more likely it was that a student would remain in an engineering degree program until they graduated (Allen & Robbins, 2008). Even though academic disengagement may arise or increase during the sophomore year and beyond and may even lead to attrition from engineering and other technical fields, a strong first-year academic performance, driven by academic engagement and strategies for meaningful learning, could mitigate such attrition (Downing, 2009; Gore, 2006).

2.2.2.2 Academic Disengagement Prevents Formation of Conceptual Knowledge

Both poor academic preparation and the resulting lack of ability to apply knowledge to alternative contexts, which enhances integration with a chosen academic program by building competence, can be linked to the elusive nature of conceptual knowledge, which exists at both the pre-college and college levels. A number of studies have contained testimonials from students about their struggles to acquire conceptual knowledge in technical subjects (Geisinger & Raman, 2013; Litzinger, et. al., 2011; Prince & Felder, 2006; Seymour & Hewitt, 1997). The consequences of a failure to develop conceptual knowledge early and often were also detected in a review of studies in attrition from engineering majors (Geisinger & Raman, 2013). Nearly half of their sources linked low grades with the failure to develop conceptual knowledge, especially in technical courses, and concluded that academic disengagement that arose from this cause for poor grades often led to attrition (Geisinger & Raman, 2013).

One example of the difficulty in developing conceptual knowledge was offered by a student who was interviewed by Seymour and Hewitt (1997), who described it as the ability to visualize the subject, which was difficult to do when the subject's concepts could not be associated with a physical phenomenon. Students often relate new knowledge to something that they can see, or have seen in the past, as an example of how new knowledge is often easier to assimilate when it can be associated with either a physical object or some other association, such as prior knowledge about something related to it (Ambrose, Bridges, DiPietro, Lovett & Norman, 2010).

When course material is taught deductively, beginning with theory and ending with applications, students often struggle with developing conceptual knowledge, especially within the relatively short timeframe needed to cover the large quantities of material found in many technical courses (Prince & Felder, 2006). Applications should be relevant to the students' experience, initiating interest and the assignment of value based on usefulness (Prince & Felder, 2006). Similarly, students are more willing to learn something new when they find it to be both useful and interesting; usefulness and interest are two elements of the MUSIC model of motivation (Jones, 2009, 2018).

Deliberate, guided practice over time contains a combination of both deductive and inductive learning (Prince & Felder, 2006). It also requires a sufficient amount of time and commitment, which disengaged students are often not willing to invest because they are more inclined toward superficial or "surface" learning rather than conceptual or "deep" learning (Biggs, 1988, 2003; Litzinger et al., 2011).

The fact that knowledge is often presented and assimilated sequentially in technical courses further compounds the problem with developing conceptual knowledge, especially when the current subject requires knowledge that has been previously acquired and assumed to have been retained (Seymour & Hewitt, 1997). Just as a child needs to be able to walk before they can run, there is no doubt that students need to develop a set of what Ambrose, et al. (2010) called "component skills", which should be coupled with applications in order to enable students to practice integrating these two aspects of learning and, ultimately, learn how to apply concepts to applications.

2.2.3 Impact of Academic Disengagement on Future Success

Engineering and other college students expect that their education will prepare them for a successful career, but a failure to engage with the academic aspects of higher education can have long term consequences for careers as well as a lack of personal satisfaction with having met a long-sought goal. While attrition from an engineering program, for example, may seem to be an extreme case, there are more widespread consequences to the engineering profession and its role in the industrial workplace and other sectors of modern society, as the demand for engineers seems to increase, but the supply does not.

2.2.3.1 Academic Disengagement Leading to Attrition

Academic disengagement in either the first or second year has been linked to approximately 40% attrition from engineering and other academic programs, although other factors may also influence the decision to leave these programs, such as lack of interest caused by alternative career interests (Chen & Soldner, 2013; Cherif et al., 2015; Eris et al., 2010;

Geisinger & Raman, 2013; Ohland et al., 2008). Moreover, this estimated 40% rate of attrition does little to meet the continuing demand for even more technically-oriented graduates in the future (Chen, 2015; President's Council of Advisors on Science and Technology (PCAST), 2012). Demand arises from the continuing and expanding need to develop and support emerging technologies and the increased importance of the role of technology in society (Institute of Medicine, National Academy of Sciences & National Academy of Engineering, 2007; President's Council of Advisors on Science and Technology (PCAST), 2012; Seymour & Hewitt, 1997). My study is limited to the implementation of learning approaches and strategies to mitigate the threat of academic disengagement by promoting short-term and long-term academic success and persistence in the engineering profession, whereas the exploration of additional factors leading to attrition are beyond the scope of this study.

Specifically, one million additional technical professionals will be needed in the American workforce, in addition to an existing projection of one million new technical professionals expected to graduate between 2012 and 2022 (President's Council of Advisors on Science and Technology (PCAST), 2012). Concerns about attrition from technical programs began to arise in the early 1990s in response to growing disenchantment with the quality of mathematics and science education (Seymour & Hewitt, 1997). Scientific and engineering education systems, at that time, had failed to meet the nation's need for a technically-literate population, as well as provide sufficient numbers of engineers, scientists, and mathematicians to meet the emerging demand for meaningful technical contributions to the resolution of socioeconomic problems (Seymour & Hewitt, 1997). Meanwhile, academic disengagement, exacerbated by negative impressions of the academic environment in technical courses, was a fundamental cause of attrition from technical majors to either non-technical majors, or leaving college altogether (Seymour & Hewitt, 1997).

Chen (2015) also explored the reasons for attrition from technical programs between 2003 and 2009, both in terms of leaving higher education without any degree or certificate and switching to a non-technical program. Two types of attrition, "dropouts" and "switchers," were the study variables, and were explored for three levels of academic performance: low, moderate, and high (Chen, 2015). The percentages of "dropouts" vs. "switchers" are shown in Table 2.1.

Table 2.1: Dropout and Switching Percentages by Type of Academic Performance
(Note: high performance does not necessarily indicate greater engagement)

Type of Academic Performance	**Data Source**	**Left college entirely**	**Switched to a non-TECHNICAL major**
Low	(Chen, 2015)	57	14
Moderate	(Chen, 2015)	15	32
High	(Chen, 2015)	10	26
Engineering students	(Chen & Soldner, 2013)	20	21

On an overall basis, 20% of all students entering a technical program left college entirely and 28% switched to a non-technical program (Chen, 2015). The overall rate of attrition, at 41%, corresponds to the rates indicated by Seymour and Hewitt (1997), Ohland, et al. (2008) and Eris, et al. (2010). Students were leaving technical programs even when they were performing well in them.

2.2.3.2 Barriers to Broader Participation in Engineering

Disengagement and attrition also work against broadening participation in engineering from a socioeconomic and global perspective (Godwin, Potvin, Hazari & Lock, 2016). As problems within society and between societies become more complex, potential solutions need to be more creative and innovative. Engineers with diverse backgrounds and experiences can make these solutions possible (Godwin et al., 2016). Since it is the mission of engineering to make life better for people, an engineering community should also become more representative of the people served by that community, in order to develop and implement acceptable solutions for those whom they serve. The effort to broaden participation is ongoing, because engineering has not been a sufficiently attractive career choice for continually underrepresented demographic groups (American Society for Engineering Education (ASEE), 2009).

Still another factor working against greater participation in engineering programs, in particular, is the reputation that engineering is a "closed club" of white men (Ohland et al., 2008). Seymour and Hewitt (1997) attempted to explain this exclusion by stating that engineering programs were more academically selective than other technical programs in admitting students, which is a reflection of the accessibility of or opportunity for pre-college preparation. The sense of exclusiveness and importance of prior preparation was further supported through findings that inward migration into engineering did not offset attrition (Ohland et al., 2008). This means that students who transfer into engineering from other disciplines often do not have the type of prior technical preparation as those who entered college as engineering majors and may find themselves at an unsurmountable disadvantage.

The greatest advantage to be gained from broader participation in engineering is the capability for better solutions and products, more creative teamwork, and, most importantly, a better educated and informed citizenry (Chubin, May & Babco, 2005). If engineers can develop the cultural competence to work with others who have different backgrounds and views from their own within the United States, then they would be better able to respond to the challenges found in the global workplace, thereby increasing the success and influence of their organizations (Chubin et al., 2005). The mitigation of academic disengagement among disadvantaged groups, in particular, is an important step in retaining these groups in the engineering profession. However, adjustments to the current engineering climate are also necessary in order to recognize and leverage the diversity of skills and perspectives among all engineers for the expansion and advancement of the engineering profession.

2.3 Learning Approaches and Strategies to Mitigate Academic Disengagement

This section contains a more detailed description of the framework developed by Biggs about learning strategies of college students (Biggs, 1988, 1996, 1999; Biggs & Tang, 2011) and includes a comparison to studies by other educational researchers that relate to one or more of Biggs' concepts. These studies explored how students actually learn in a university setting, as well as how educators can help them to learn more effectively for knowledge retention and transfer. A summary of research methods for exploring learning approaches and strategies is also included as background information for the methods that I will employ in my study.

2.3.1 Biggs' Underlying Framework for Learning: Product and Process

I am applying Biggs' framework for approaches to learning as a lens to explore my research question and sub-questions about learning approaches and strategies among first-year engineering students (Biggs, 1988, 1996, 1999, 2003). In addition to the availability of studies based on Biggs' framework, which provide a foundation for understanding its scope and boundaries, I have found the learning approaches described in this framework to be exhibited by my own students.

When students indicate their approaches to learning by their choices of learning strategies, they are answering these two questions (Biggs, 1988):

- What do I want to get out of this? (i.e., the product of study)

- How do I get there? (i.e., the process of studying)

The former question is task-, motive-, and goal-oriented, while the latter question involves the choice of learning approaches and strategies in view of available resources and constraints. This combination of task, motive, resources, and strategies was labeled as “metalearning” as a form of metacognition (Biggs, 1988).

2.3.2 Biggs’ Approaches to Learning: Surface, Deep and Achieving

Biggs’ framework was derived and further developed from the work of Marton and Säljö (1976). These researchers had identified two distinct approaches to learning from the results of various studies, in which students were asked to read a passage of text and then answer questions about it (Biggs, 1979; Marton & Säljo, 1976). Those with a “surface” approach tended to recall facts, but not the meaning behind them, while “deep” learners demonstrated that they had considered both explicit and implicit meanings of those facts. Under the “deep” approach, the quantity of information recalled did not matter as much as what it meant to the student, revealing more of the “process” of learning rather than the “product” (Biggs, 1988; Biggs & Tang, 2011; Marton & Säljö, 1976).

2.3.2.1 Surface Approach to Learning

When a student uses a “surface” approach to learning, they are extrinsically motivated to meet external requirements to the minimum extent possible. A student who just wants to “get by” in a course will most likely use a “surface learning” approach, such as rote memorization or only working on the problems shown in class. The “surface” approach has a focus on signs or labels, rather than on meaning and understanding (Biggs, 1979). The “surface” approach may also be an example of academic disengagement, specifically “values disengagement,” where the student’s values are not compatible with those of the institution, its faculty, or the course in question (Brint & Cantwell, 2014).

2.3.2.2 Deep Approach to Learning

A student who pursues a "deep" approach to learning is intrinsically motivated to understand the study material thoroughly and seek additional knowledge related to it. This student is more likely to employ learning strategies such as planning, summarizing, self-monitoring, self-questioning, self-evaluation, reflection, and the exploration of concepts in alternative contexts than the "surface" learner (Biggs, 1988; Ganz & Ganz, 1990).

While many educators aspire for their students to achieve "deep" learning, circumstances and the need for expediency often produce "surface" learning. Beginning in the late 1980s, Biggs bemoaned the fact that many more of his students were now taking the "surface" learning approach rather than the "deep" learning approach than he had observed among his students during the 1970s (Biggs, 1988, 1999, 2003). My own observations of how my students complete their work indicate that this is still largely the case.

2.3.2.3 Achieving Approach to Learning

In the "achieving" approach, which is a context-dependent combination of strategies associated with either the "surface" or "deep" approach, the choice of strategies depends on what is necessary to achieve a high grade (Biggs, 1988, 1999). The student who uses this approach is likely to plan how they will study, and to allocate the greatest amounts of time and effort to those subjects for which their perceived probability of success is high.

2.3.2.4 Biggs' Study Processes Questionnaire

Biggs developed and refined his study processes questionnaire (SPQ), which was originally based on personality, cognitive style, and IQ factors, along with environmental factors such as home and institutional environment, teaching and evaluation methods, and course structure (Biggs, 1978, 1979, 1988). The SPQ contained ten interdependent scales to identify students' approaches to learning, as shown below (Biggs, 1978):

- Pragmatism: grade and degree attainment are the means to a goal;
- Intrinsic academic motivation: university study is intrinsically rewarding;
- Academic neuroticism: confusion over course demands;
- Internality: critical evaluation of information before its acceptance as "truth";
- Study skills: conscientious, consistent, and diligent approach to schoolwork;
- Rote learning: facts and details are memorized;
- Meaningful learning: new information is compared to prior knowledge; search for understanding;
- Test anxiety;
- Openness: values can be questioned openly in the university, and
- Class dependence: need for structure and a reliance on authority.

The reliability of these scales was demonstrated by listing their Cronbach alpha values in the range of 0.50 to 0.82, indicating average to high reliability. By 2001, the SPQ had been modified to focus more directly on the "deep" approach than the "surface" approach, in order to meet the emerging need to better understand the nature of student learning in more complex contexts than were present in the late 1970s (Biggs, et al., 2001).

2.3.3 Additional Insights into Learning Approaches and Strategies

The additional insights explored in this section include motivational and metacognitive factors that affect academic engagement and how they complement one another in the exercise of self-regulating learning strategies. The importance of guided practice in learning approaches and strategies is also described, along with the rationale for specific examples of effective forms of guidance.

2.3.3.1 Motivational Factors for Learning Engagement

The MUSIC model of academic motivation contains five motivational components: empowerment, usefulness, success, interest and caring (Jones, 2018). Three of the five components of the MUSIC model of academic motivation relate more directly to students' learning approaches and strategies than the others; namely, empowerment, usefulness, and success.

Empowerment is a motivating factor for academic engagement because students who feel empowered to take control of their learning become engaged in it as a result (Jones, 2018). Control over learning also allows students to accept epistemological beliefs about the nature of knowledge as contextual, uncertain, and dynamic (Buehl & Alexander, 2001). For example, when a student engages in the "deep" learning strategies of self-questioning or reflection about knowledge gained through course work or elsewhere, they now realize what aspects of knowledge can and cannot be known with certainty. The act of organizing and integrating certain items of knowledge into a cohesive set of fundamental concepts, along with the necessary assumptions and exceptions, empowers students to identify concepts that they understand easily, those concepts that reveal new ways of thinking, and troublesome concepts that seem to defy understanding and mastery (Male & Baillie, 2015).

Engagement is also influenced by usefulness or value, as students are willing to invest time and energy into learning when they believe that such investments will produce something that is useful for them to meet their goals (Jones, 2018). The importance of students' perceived value of a course and their subsequent engagement was the focus of a 2009 study that was based on Biggs, Kember and Leung's modified study processes questionnaire (Biggs et al., 2001; Floyd et al., 2009). These results revealed a positive, significant correlation between student engagement and the "deep" learning approach and a significant negative correlation between perceived course value and the "surface" learning approach (Floyd et al., 2009). Students might fail to recognize the value of a course if they neglect to explore its meaning in any degree of depth. Those students exercising a "deep" approach would be more engaged with the course material and therefore with the course in general. It also follows that value is not necessarily obvious; sometimes it requires "deep" processing in order to be revealed.

Success, or the perception of success through self-efficacy, is motivating when students believe that they can be successful with an appropriate amount of effort (Jones, 2018). Downing (2009) explored self-efficacy by administering the Learning and Study Strategies Inventory (LASSI) to 300 entering undergraduate students, again after fifteen months or three semesters of university study, and a third time just prior to graduation, respectively. Results were derived by analyzing the LASSI scores within three groups, consisting of participants with a low GPA, medium GPA, and high GPA, respectively, for each stage of the undergraduate curriculum.

In Downing's study, entry-level students showed little difference in metacognitive abilities for study skills, will, and motivation among the three GPA groups, but this changed dramatically by the end of the study period. Improvement was first noted at the 15-month mark, when the high-GPA group demonstrated statistically significant levels of improvement over the other two groups (Downing, 2009). The research group explained this difference in terms of self-efficacy, along with the social influences that enhance or diminish it; i.e., that low-achieving students will exhibit eroding self-efficacy, based on past and existing poor performance (Downing, 2009). These results also provided evidence for the component of Bandura's self-efficacy theory about prior success: that self-efficacy in an area is enhanced by prior success in that area and that a lack of prior success could erode self-efficacy (Bandura, 1977a, 1977b; Downing, 2009). Earlier studies underscored the importance of this aspect of self-efficacy by asserting that first-year students need to develop academic self-efficacy because it is a good predictor of academic success in college (Allen & Robbins, 2008; Gore, 2006; Robbins et al., 2004).

2.3.3.2 Metacognitive Factors for Learning Engagement

If motivation provides the impetus to take control over learning, metacognitive skills facilitate academic engagement through specific learning strategies. While learning strategies such as memorizing, self-questioning, and evaluation directly facilitate learning, metacognitive strategies involve choices about which learning strategies to use, how to use them, when to use them, and why they are useful (Pintrich, 2002). Another illustration of the role of metacognition in learning involves the ways that students direct their thinking, such as how they integrate new information with existing knowledge, decide how to think when solving problems, and allocate their available resources in accordance with their goals (Dirkes, 1985).

The origins of the study of metacognition are commonly attributed to Flavell (1979) and were later expanded by Pintrich (2002); Veenman and Verheij (2003); Downing (2009); McCord and Matusovich (2013); Medina, Castleberry and Persky (2017); and Moritz and Lysaker (2018). Metacognitive learning strategies have also been shown to be necessary for sustainable academic success, as demonstrated by Biggs (1988); Jackson (2004); Felder and Brent (2005); Downing (2009); and Cunningham, Matusovich, Hunter, Williams and Bhaduri (2017).

Flavell (1979) proposed the following theory of metacognition through four categories, which were later expanded by Moritz and Lysaker (2018):

- Metacognitive knowledge: how people exercise elements of cognition through tasks, actions, experiences, and goals;
- Metacognitive experiences and strategies: awareness of cognitive and/or affective reactions to a thought, idea, or revelation, and responsive actions;
- Metacognitive goals: determine a necessary level of understanding or performance, and
- Actions and strategies: the decision to act, or judgments about how to respond to or regulate what has been said or done, as well as the action itself.

Of these four categories of metacognition, metacognitive knowledge and metacognitive experiences with strategies will be investigated further in this section.

Metacognitive knowledge is a set of beliefs about how people act and what cognitive and metacognitive strategies they might use to direct their actions (Flavell, 1979). This knowledge also includes beliefs about oneself, such as an appraisal of abilities within a domain or the recognition of a preferred learning style (Flavell, 1979). In addition, since understanding is formed in stages and does not remain constant, due to the changing availability of information and one's ability to interpret this information, misunderstanding can also occur (Flavell, 1979).

An example of how understanding changes over time is when the recall of an event fails to retrieve its entire content or context (Flavell, 1979). Fundamentally, Flavell's concept of metacognitive knowledge emphasized a continual interaction between an individual's actions and their strategies for acting, both within the individual and in how the individual perceives the actions and strategies of others by making assumptions about their underlying thoughts and motives.

Metacognitive experiences and strategies are an embodiment of the general description of metacognition as “thinking about thinking”; i.e., being conscious of how one is thinking, especially in situations requiring deliberate thought prior to action (Flavell, 1979; Medina, et al., 2017). When a student chooses a “surface”, “deep” or “achieving” approach to learning, they are making a conscious decision about how to approach their coursework. These situations may be novel, important or risky, and may also prompt reflection about prior experiences and their consequences (Flavell, 1979). Despite the simplicity or complexity of a problem or the academic discipline or profession that are involved, both cognition and metacognition prompt the use of both responsive and reflective learning strategies (Medina, et. al., 2017).

A distinction should be made between the differences between the use of cognitive and metacognitive strategies in responding to a metacognitive experience. Flavell (1979) stated that cognitive strategies are used to make progress in learning, such as what has previously been identified as one or more types of learning strategies involved in assimilating information by various means (Flavell, 1979). Conversely, metacognitive strategies are those learning strategies that involve awareness, monitoring, questioning, synthesis, and evaluation (Cunningham, et al., 2017; Flavell, 1979; McCord & Matusovich, 2013). These strategies are also associated with Biggs’ “deep” approach to learning, and represent the regulation of one’s learning (Biggs, 1979, 1988). Therefore, learning strategies, as explored in my study, will involve both cognition and metacognition (Flavell, 1979).

2.3.3.3 Motivation and Metacognition in Self-Regulating Learning Strategies

Self-regulating learning strategies, which are metacognitive in nature, enable students to exert greater control over their learning so that their efforts are more likely to enable them to achieve their academic goals. These strategies are most often associated with the "deep" or "achieving" learning approach. It is clear, from the MUSIC model of motivation, that students need to have greater control over their learning, through the "deep" learning approach, in order to be successful (Biggs, 1988; Litzinger et al., 2011; Male & Baillie, 2015; Pintrich, 2003; Streveler, Brown, Herman & Montfort, 2015). For example, the strategy of re-writing class notes is a self-regulating effort to take control of material in order to make sense of it, compare it to prior knowledge for possible relationships, and decide for oneself what it means.

Some examples of self-regulating learning strategies include summarizing, self-monitoring, self-questioning (either prompted by or prompting reflection), and self-testing. These strategies are also forms of intentional action toward more meaningful learning. This intentional action is an application of the constructivist worldview, in which learning is the result of action by the learner (Garrison, 1997).

When Karpicke, Butler and Roediger (2009) conducted a survey of 177 undergraduate students about their learning strategies, they found that re-reading their notes and/or textbooks was mentioned most often, followed by working practice problems (Karpicke et al., 2009). However, only 10.7% of their study participants mentioned the metacognitive strategy of self-testing, which these authors considered crucial for the retention of knowledge (Karpicke et al., 2009). This low percentage ranked ninth out of eleven possible strategies with measurable responses (Karpicke et al., 2009).

In addition, when asked about what they would do after having read a textbook chapter once before an exam, 57.4% of the participants stated that they would just re-read the chapter or certain parts of it, 17.8% would test themselves by trying to recall the chapter's content without re-reading it, and the remaining participants would use another strategy or none at all (Karpicke et al., 2009). Apparently, the participants in this study did not believe that self-testing would improve their learning. Instead, most appeared to rely on memory and repeated reading to retain course material, rather than take ownership and exert empowerment over it, which were shown earlier to be important for academic engagement (Jones, 2018; Litzinger et al., 2011).

The implications of self-testing were also explored through a series of three studies, in 2007, 2012, and 2016, respectively (Hartwig & Dunlosky, 2012; Kornell & Bjork, 2007; Morehead et al., 2016). The survey results from these studies appear in Table 2.2 on the next page. The survey that was originally implemented by Kornell and Bjork (2007) to focus on the effect of self-testing was later modified and used by Hartwig and Dunlosky (2012) to include the influence of planning on GPA. A few years later, Morehead, Rhodes and DeLozier (2016) modified the survey again to include open-ended questions about perceptions of the efficacy of specific learning strategies for specific learning situations. The percentages shown in bold represent notable differences among the survey results.

Table 2.2: Notable Differences (in bold) in Students' Preferred Learning Strategies Among Studies by Kornell and Bjork (2007), Hartwig and Dunlosky (2012) and Morehead, Rhodes and DeLozier (2016)

Survey Question	Survey Response	(Kornell & Bjork, 2007)	(Hartwig & Dunlosky, 2012)	(Morehead, Rhodes & DeLozier, 2016)
Would you say that you study the way that you do because one or more teachers taught you to study that way?	Yes	20%	20%	36%
	No	80%	64%	64%
How do you decide what to study next?	Whatever is due soonest or overdue	59%	56%	63%
	Whatever I haven't studied for a long time	4%	2%	3%
	Whatever I find interesting	4%	5%	4%
	Whatever I feel I'm doing the worst in	**22%**	**24%**	**9%**
	I plan my study schedule ahead of time and follow it	**11%**	**13%**	**21%**
Do you return to course material after a course has ended?	Yes	**14%**	**23%**	**28%**
	No	86%	78%	72%
If you quiz yourself while you study, why do you do so?	I learn more that way than I would through reading	**18%**	**27%**	**31%**
	To figure out how well I have learned the information that I'm studying	68%	54%	49%
	I find quizzing more enjoyable than reading	4%	10%	9%
	I usually do not quiz myself	9%	9%	12%
Which of the following strategies do you use regularly? (Please (check all that apply)	Test yourself with questions or problems	N/A	71%	72%
	Use flashcards	N/A	62%	54%
	Re-copy your notes	N/A	33%	33%
	Re-read chapters, articles, notes, etc.	N/A	66%	67%
	Make outlines, underline, or highlight while reading	N/A	**22%**	**53%**
	Make diagrams, charts, or pictures	N/A	**15%**	**24%**
	Study with friends	N/A	50%	48%
	Cram a lot of information the night before a test	N/A	66%	53%
	Ask questions or otherwise participate in class	N/A	37%	25%

At its core, learning involves the assimilation of knowledge that will be stored in memory for retrieval on demand. Self-testing, in particular, provides a demand to retrieve information from memory, and, when practiced regularly, can be highly effective in strengthening the retention and retrieval of information (Kornell & Bjork, 2007; Morehead et al., 2016).

In general, results from the Morehead, Rhodes and DeLozier study revealed greater overall agreement with the results of Hartwig and Dunlosky than those of Kornell and Bjork. A tendency to study in response to deadlines was evident in all three studies, although deliberately planning one's study schedule, whether in response to deadlines or otherwise, was more common among the students in the 2016 study than in the others (Hartwig & Dunlosky, 2012; Kornell & Bjork, 2007; Morehead et al., 2016).

However, the "planning" response did not contain the provision that a student might plan to study certain subjects in a certain order according to their relative homework, project, or test deadlines, which is an example of how responses might vary among courses. This lack of differentiation among courses provides additional evidence that the possible differences in learning strategies among a student's courses are worth exploring through my research question and sub-questions.

With respect to self-testing, the response, "to figure out how well I have learned…" was chosen by 49% or more of the participants in all three studies, which indicated that they recognized the metacognitive benefit of monitoring and evaluating their own learning as a way to decide how much longer or more often to study any given subject (Hartwig & Dunlosky, 2012; Kornell & Bjork, 2007). The decision to continue studying a subject can also influenced by a "region of proximal learning," which is a state in which the student continues to learn at what they determine to be a satisfactory or meaningful rate (Metcalfe & Kornell, 2005; Vygotsky, 1962).

2.3.3.4 The Role of Faculty to Promote Meaningful Learning Strategies

Faculty need to take an active role in guiding their students toward more meaningful learning approaches and strategies, because the value of academic engagement is not always as obvious to the student as it is to the instructor (Felder & Brent, 2005). In order for guided practice to be useful, it should be implemented through the constructive alignment of course objectives, activities, and assessments to promote a "deep" approach to learning, which leads to greater academic engagement (Biggs, 1989, 1996; Biggs & Tang, 2011).

Since students may or may not use learning strategies that are taught in isolation, Pintrich advised that these strategies be embedded in course material rather than taught separately, while Flavell favored either an embedded or separated approach (Flavell, 1979; Pintrich, 2002). By providing students with the application of cognitive and metacogntitive learning strategies, rather than just the explanation, Pintrich's recommendation would result in the active use of tools rather than merely their acquisition, which would be realized through guided practice in the classroom (Brown, Collins & Duguid, 1989; Pintrich, 2002). When applied to engineering education, the active use of metacognitive skills and tools is an example of an inductive approach to learning through application, rather than a deductive approach based on lecturing about how to use learning strategies (Felder & Brent, 2005).

Another 2012 study used a survey to explore a relationship between approaches to learning and student disengagement (Baldwin & Koh, 2012). Results revealed a major problem where incoming students' learning styles were incompatible with what was expected of them by their professors, which these researchers attributed to the teaching and learning environment in these students' high schools (Baldwin & Koh, 2012). After responding to the teacher-as-expert mode of instruction for many years, it was logical that many first-year students would expect a similar mode of teaching and learning in college, where it did not necessarily exist (Baldwin & Koh, 2012).

The results of the Baldwin and Koh study also implied that course workload and assessment methods exerted a heavy influence on the learning approaches that these students would take. Inasmuch as many university educators expect their students to use an active, "deep" approach to learning, resource limitations on the part of students (i.e., time, energy, and cognitive limits), along with "sink or swim" course expectations, may cause these students to adopt a passive or "surface" approach out of perceived necessity (Baldwin & Koh, 2012). Here is a case in which students formed their learning strategies based on expediency and instructors applied a system that encouraged the use of "surface" learning approaches and strategies to meet grading expectations.

2.4 Engagement with Learning Through Reflection

Reflection in the context of learning involves a search for the meaning behind what is learned, and has been described by a collection of social science and educational researchers whose work will be included in this section. Reflection enhances learning and is an important contributor to meaningful learning strategies. My second research sub-question explores the ways in which students use reflection as a learning strategy to impart meaning to what is being learned.

2.4.1 An Overview of Reflection in Learning

When reflecting on an experience, the individual re-visits it in their mind with the idea that there is more to it than what was seen or heard. Why did something happen, and what does it mean? Deciding how important the item of knowledge or the event is may also involve what it reminds one of, or what else can be learned from it. Kember, McKay, Sinclair, and Wong (2008) described reflection as a "re-examination and evaluation of experience, beliefs and knowledge" and asserted that reflection was necessary to solve ill-structured problems, which engineers and other professionals encounter in the workplace on a regular basis.

Reflection is a form of mental processing, but many students in a learning environment tend to reflect on a superficial level (Moon, 2004, 2007). This superficial level resembles the "surface" approach to learning (Biggs, 1988). The concept of reflection as mental processing can be further described as a careful, continuous examination of knowledge and beliefs in view of supporting evidence (Leung & Kember, 2003). Reflection can also be directed at a specific outcome or used to ponder a question or problem that does not have an obvious solution (Moon, 2004, 2007). Review, interpretation, and understanding of experiences are reflective and useful strategies for future behaviors and actions (Wald, et. al., 2012).

Reflection is also a useful strategy for professionals, in the form of reflection-in-action (Schön, 1983, 1987), which involves momentary reflection about an event that has just occurred or about a newly discovered item of knowledge. Engineers in particular, both professionals and students, need to employ reflection-in-action in order to succeed at their work, because the ability to reflect in the moment as well as retrospectively informs and enhances the ability to think critically and become more flexible in accepting alternative points of view. (Schön, 1983, 1987). Students benefit from reflection-in-action when college curricula contain courses that build on one another to form a collective body of knowledge in a specific discipline, where reflection prompts the recognition of similarities among courses.

2.4.2 Conceptual Models to Characterize Reflection in Learning

The cognitive concepts underlying reflection in learning are described in this section through two models that show beliefs about knowledge and five models that show how those beliefs are enacted through several stages of reflection. Each model for beliefs about knowledge begins with the belief that knowledge is absolute and unchanging, and is obtained from authority without question. Similarly, the reflection models begin with non-reflection, or the automatic assumption that whatever is encountered must be true and complete, and that its meaning is obvious. As each model progresses to its next stage, concepts of knowledge and/or meaning become more uncertain and complex, and what was formerly assumed to be true in all contexts is found to vary with context, thereby changing its meaning. The developers of these models found that it was necessary to incorporate the dynamic, changing nature of knowledge into their models in order to describe it realistically, and to show how reflection also evolves into a multifaceted aspect of learning

2.4.2.1 Reflective Judgment and Intellectual Development Models

Table 2.3 provides a side-by-side comparison of King and Kitchener's reflective judgment model with Pavelich and Moore's interpretation of the Perry model of intellectual development (King & Kitchener, 1994; Pavelich & Moore, 1996; Perry, 1999). These models illustrate how reflection reveals beliefs about knowledge as well as the meaning of knowledge itself by questioning the certainty of knowledge in view of its dynamic nature and its tendency to be influenced by context.

The term, "reflective judgment" identifies levels of knowledge in terms of judgment about how knowledge can change with context (King & Kitchener, 1994). Context includes events, actions, and the individuals who cause or are affected by them, all of which serve as sources of evidence for the formation of judgments about the validity of knowledge. King and Kitchener's Reflective Judgment Stages (1994) consisted of seven stages of thinking that progressed from an absolute certainty of knowledge to knowledge that evolved by a process of reasonable inquiry and judgement about ill-structured problems and their solutions. This judgment was based on evidence from a wide variety of sources.

Table 2.3: Stages of Intellectual Development According to King and Kitchener (1994) and Pavelich and Moore (1996)

Stage No.	King and Kitchener's Views About Knowledge	Pavelich and Moore's Views About Knowledge
1	Is absolutely certain and concrete, based on observation	Is right or wrong, a collection of facts obtained from authority
2	Is absolutely certain but not immediately available, based on either observation or authority figure	Is generally right or wrong. Authority gives us the right answer or give us problems to solve in order to find it.
3	Is absolutely certain (from authority figures) or temporarily uncertain, where beliefs serve as substitute until absolute knowledge is available	Is right or wrong, but some of it may be unknown. Authority gives the answers or the means by which to find them.
4	Is uncertain because knowing always involves some ambiguity; data are not always reliable and may be subject to error. Idiosyncratic beliefs may exist.	Is uncertain because knowing always involves some ambiguity; data are not always reliable and may be subject to error. Idiosyncratic beliefs may exist.
5	Is based on context and is subjective because it depends on individual perception and criteria for judgment.	Most of it is contextual and can be judged qualitatively or subjectively.
6	Is constructed as a series of individual conclusions about ill-structured problems; information comes from a variety of sources. Conclusions are based on evaluations of evidence across contexts and can be derived from the opinions of well-reputed others.	Is not absolute. Student accepts responsibility for making judgments and commitments based on their values.
7	Is constructed as a series of individual conclusions about ill-structured problems; information comes from a variety of sources. Conclusions are based on evaluations of evidence across contexts and can be derived from the opinions of well reputed others.	Is relative. Judgments are made among alternative views, and doubt is recognized and accepted.

With a focus on experiential learning, or learning by doing, in an engineering context, Pavelich and Moore (1996) used the Perry model (Perry, 1999) to measure their students' intellectual growth over four years of college. Experiential learning involves reflection when students questioned their assumptions and thereby identified alternative solutions in view of the direct evidence that doing something reveals more knowledge than observing it being done. They assumed that, given frequent exposure to real-world, open-ended, ill-defined projects intended to promote experiential learning, that students would learn to handle these types of problems in a reasoned, defensible manner and would regard the outcomes of their work as a means to achieve intellectual growth.

However, Pavelich and Moore found that, even after practice using experiential learning methods, many students still held deep-seated beliefs about the nature of knowledge and the lack of alternative solutions to real-world problems, which prevented them from expanding their intellectual growth, according to the Perry model (Pavelich & Moore, 1996). These findings were later included in a review of models of intellectual development by Felder and Brent (2004), who compared the Perry model to their own four-stage model, and also found that their own students exhibited similar approaches and strategies for learning.

The more advanced stages of the Pavelich and Moore (1996) and King & Kitchener (1994) models were based on an epistemology evolving from a process of reasonable inquiry and judgment about ill-structured problems and their solutions. Reflection can also reveal whether evidence is sound or questionable, such as in the use of the self-questioning and other self-regulating learning strategies identified by Biggs as one distinction between "surface" and "deep" approaches to learning (Biggs, 1999, 1988).

2.4.2.2 Five Additional Conceptual Models for Reflection

Table 2.4, on the next page, shows a series of conceptual models focusing on reflection. Of the five models listed, I will apply the one developed by Kember, McKay, Sinclair and Wong (2008) to my study. The remaining reflection models were developed by Chabon and Lee-Wilkerson (2006), Hatton and Smith (1995), Moon (2004) and Sparks-Langer, Simmons, Pasch, Colton and Starko (1990).

Table 2.4 also indicates where the stages of one or more models resembles or complements one or more stages of the others. Each model begins with an epistemology in which all knowledge is supplied to the individual externally, through events, actions, and other sources of information originating with others, and is assumed to be absolutely true. Any gap in knowledge, such as uncertainty or ambiguity, is resolved through the release of knowledge that is temporarily unknown. Subsequent stages describe how this authority-based epistemology changes with the acceptance of uncertainty and ambiguity that arises from the awareness of multiple contexts, opinions, and beliefs. At the highest levels, the learner accepts that the opinions and beliefs of others are equally valid with respect to their own.

Table 2.4: Side-by-Side Models of Reflective Thinking by Kember, McKay, Sinclair & Wong (2008), Chabon & Lee-Wilkerson (2006), Moon (2004), Hatton & Smith (1995) and Sparks-Langer, Simmons, Pasch, Colton and Starko (1990)

(Kember, McKay, Sinclair & Wong, 2008)	(Chabon & Lee-Wilkerson, 2006)	(Moon, 2004)	(Hatton & Smith, 1995)	(Sparks-Langer, Simmons, Pasch, Colton & Starko, 1990)
Habitual Action: information is placed into a document with no reflection or significant thought about it or attempts to interpret or understand it.			**Descriptive Writing**: not reflective, just a description of events, with no attempt to provide reasons or justifications.	Simple, layperson description, with no supporting detail.
Understanding: student attempts to understand the topic by searching for the meaning implied by the author, but without any reference to their own experience or potential application.		**Descriptive Writing**: Contains little reflection, events are listed in chronological order, emotions are not explored, external ideas are not questioned, lack of focus on specific issues.	**Description with a Little Reflection**: contains an attempt to provide justification for a position, but not reflectively. States what the writer believes, but not why.	Events labeled with appropriate terms for the subject matter.
	Descriptive Reflection: new knowledge is described with an attempt to make sense of it and/or link it to prior knowledge.	**Description with Some Reflection**: indicates points for reflection but does not explore them, little to no reference to ideas from outside the event.	**Descriptive Reflection I**: recognition of one perspective or view as a rationale.	Explanation with traditional or personal preferences given as the rationale.
Reflection: student attempts to compare what they learned to personal experience and relates theory to one or more practical applications.	**Empathic Reflection**: thinks about and possibly challenges prior beliefs of self and others. Demonstrates a sensitivity to the values and beliefs of others.	**Reflection Level 1**: Description contains specific aspects for reflective comment, inclusion of external ideas/information, some exploration of motives for behavior, self-questioning, possibly criticism of others.	**Descriptive Reflection II**: recognition of multiple perspectives or views.	Explanation with principle or theory given as the rationale.
	Analytic Reflection: considers multiple contexts in both professional and personal life. Examines, compares, contrasts, proposes actions and remedies for problems.		**Dialogic Reflection**: Steps back from the immediate situation and considers possible alternative views or contexts to explain or form a hypothesis, based on one or more perspectives or views.	Explanation with principle or theory along with contextual factors.

Critical Reflection: involves a transformation of one's perspective, or a paradigm shift. Deep-seated beliefs are questioned and re-formed in light of new information and experience.	**Metacognitive Reflection**: examines the learning process and how one's new knowledge influences prior knowledge and beliefs.	**Reflection Level 2**: Description focuses on issues for reflection, to the exclusion of extraneous information, taking an external view of the event, accepting how the frame of reference can change, comparison of one's views with those of others.	**Critical Reflection**: recognizes multiple perspectives along with multiple historical and socio-political contexts.	Explanation with consideration of ethical, moral, societal, or political issues.

The four-stage model by Kember and associates (Kember, 1999; Kember et al., 2000; Kember et al., 2008; Leung & Kember, 2003) begins with Habitual Action, then proceeded to stages of Understanding, Reflection, and Critical Reflection. The first and second stages addressed what students had learned, the third stage identified importance and meaning, while the fourth stage incorporated a transformation of deep-seated beliefs, or a paradigm shift. In analyzing a document containing reflection, the highest level of reflection exhibited should be considered as indicative of the entire document (Kember, et al., 2008).

A similar four-stage model by Chabon & Lee-Wilkerson (2006) included a search for meaning in the first stage, such as through the comparison of new knowledge to prior knowledge. Later stages in this model linked reflection to the questioning of beliefs about knowledge, leading to a synthesis between new and existing knowledge, which may or may not have resulted in changes in original beliefs. As with the Kember model, Chabon & Lee-Wilkerson (2006) recognized social influences and experiential input as major sources of information for the formation of knowledge.

Moon (2004, 2007) asserted that students in a learning environment tended to reflect only on a superficial level, which resembled Biggs' observations about "surface learning" (Biggs, 1988). Moon's highest stage took an external view of events and recognized changes in context, which are also important aspects of meaningful learning. (Bransford, Brown & Cocking, 2000; Moon, 2004, 2007). In addition, review, interpretation and understanding experiences are useful aspects for future behavior and action, which also contributed to learning, often through others, as additional benefits of reflection (Wald et al., 2012). Moon's stages of reflection were also considered by Leung and Kember (2003), who defined reflection as a careful, continuous examination of knowledge and beliefs in view of supporting evidence, such as contact with people and events.

More detailed reflection models by Sparks-Langer, Simmons, Pasch, Colton & Starko (1990) and by Hatton & Smith (Hatton & Smith, 1995) were developed from the field of teacher education, from studies in which teachers reflected on their teaching methods and how their students responded to them. While Moon's stages are concentrated in the early transition from information without interpretation, and Chabon & Lee-Wilkerson's stages begin with attempts at meaning through comparison and context, the Kember stages are more or less equally distributed over the continuum of the Sparks-Langer and Hatton-Smith stages, as shown in Table 2.4 (Chabon & Lee-Wilkerson, 2006; Hatton & Smith, 1995; Kember et al., 2008; Moon, 2004; Sparks-Langer et al., 1990).

2.4.3 How Reflection Reinforces Learning Approaches and Strategies

Students chose their approach to learning and subsequent learning strategies partially based on their beliefs about the nature and acquisition of knowledge. The conceptual models described in this section demonstrate how reflection reveals underlying beliefs about knowledge, which in turn influence choices about learning approaches and strategies.

2.4.3.1 Reflection with Self-Regulating Learning Strategies and Guided Practice

Learning strategies become more useful to both students and educators when reflection is employed to provide the meaning, relevance, and limitations to what is being learned. The theoretical frameworks that I have used for learning strategies and reflection contain a number of complementary elements, which are offered in this section as evidence for the relationship among my research question and its sub-questions.

While the “surface” learning approach and its associated strategies are largely devoid of reflection, “deep” learning strategies involve the exploration of knowledge in multiple contexts in order to discover its meaning and recognize its gaps, uncertainties, and ambiguities. The “deep” learner reflectively seeks the meaning of what they are learning within the dynamic, ever-changing nature of knowledge and will readily question what they see or hear (Biggs, 1999; Biggs & Tang, 2011).

The “achieving” approach and strategies use reflection along with planning and evaluation to set goals, establish the steps to achieve them, and measure progress toward attaining them (Biggs, 1988, 1996; Moon, 2004, 2007). The “achieving” learner may also use reflection to determine the value or usefulness of what they are learning to their identified goal of higher grades, whereby the value of a particular body of knowledge is a motivating factor for mastering it (Jones, 2018; Wigfield & Eccles, 2000).

Active learning techniques, such as problem-based learning, encourage all students to develop the higher-level cognitive skills associated with the “deep” approach (Biggs, 1999). On this basis, the willingness to question assumptions, propose alternative solutions, and evaluate the validity of conclusions involve reflection on what something appears to be and whether or not to accept it as valid. Biggs’ work in this area was extended by Leung and Kember (2003), where they linked the “deep approach” to reflection through the student’s search for meaning or association of new knowledge with their existing knowledge. By contrast, the “surface” approach was no more than action by habit (Leung & Kember, 2003).

Another way to describe the ways in which reflection facilitates academic engagement is through “interpretive learning” (Etkina, Karelina, Ruibal-Villasenor, Rosengrant, Jordan & Hmelo-Silver, 2010). When applied to a scientific problem, interpretive learning includes the consideration of applicable principles, assumptions, sources of error, and confirmation of the results, all of which involve reflection. Instructors can implement forms of guided practice in this type of learning through problem solving with reflection; for example, in which students narrate their thought process aloud and reflect on their own problem-solving processes (Etkina et al., 2010).

Interpretive learning, or sense-making, can also be helpful for building conceptual understanding, when it involves reflection on prior knowledge and experience in order to compare similarities and differences with new knowledge. It can also involve questioning, speculating, and evaluating the validity of solutions, in which arguments are formed and then substantiated by evidence (Etkina et al., 2010). This approach to learning is similar to the "deep" approach because this approach involves a choice between engaging with an integrated body of knowledge with meaning instead of a random set of facts (Biggs, 1999).

Another form of guided practice to promote reflection as a habitual learning strategy is through drafts of reflective writing that are then rewritten into more refined products under the guidance of a "reflection leader" (Ash, Clay & Atkinson, 2005; Ash & Clayton, 2004). Prompting in this manner also encourages students to identify what they might do next as a result of reflection. Similarly, metacognition can be combined with reflection exercises in planning, modeling, monitoring and evaluation of, and reflection about past and present experiences, as in, "Where have I seen this before?" (Medina et al., 2017; van Manen, 1995).

By reflecting on how they had or had not learned course material, students realize what is needed to learn effectively (van Velzen, 2017). This results in retrospective reflection with the implication that the student would then critically evaluate their learning processes. Self-reflective thinking is also cognitively demanding, which could explain why students need guided practice and a lot of encouragement in order to develop reflective learning strategies (van Velzen, 2017).

2.4.3.2 Additional Insights into Beliefs about Knowledge Through Reflection

Learning approaches and strategies that are aided by reflection can enable students to reveal those aspects of their knowledge that are uncertain or incomplete (Kember et al., 2000; King & Kitchener, 1994; Moon, 2007; Pavelich & Moore, 1996). Reflective exploratory learning strategies, such as self-questioning, along with metacognitive self-monitoring, can provide ways to address the uncertainty and ambiguity of knowledge (Crede & Kuncel, 2008; Hartwig & Dunlosky, 2012; Karpicke et al., 2009). An example of the influence of beliefs about knowledge on learning strategies came from Ryan (1984), whose study involved reading comprehension that was later recognized by Buehl and Alexander (2001), and even earlier by Marton and Säljö (Marton & Säljö, 1976). Students were asked how they decided whether they understood certain chapters in a chosen textbook. These students were evaluating their understanding, which is a learning strategy, and their evaluations revealed that they regarded the knowledge that they gained from the textbook material in a mostly dualistic manner (i.e., right vs. wrong) or mostly relativistic manner (i.e., dependent on context) (Buehl & Alexander, 2001; Ryan, 1984).

Learning strategies are formed and practiced largely within academic environments, where schooling also affects students' beliefs about knowledge (Buehl & Alexander, 2001; Dewey, 1916). For example, the student who believes that knowledge is absolute thinks that knowledge just has to be memorized and repeated, rather than analyzed for deeper meaning. Deeper meaning can also be realized through the reflective and metacognitive learning strategies of self-questioning, self-monitoring, and self-evaluation (Crede & Kuncel, 2008; Hartwig & Dunlosky, 2012; Morehead et al., 2016).

Modeling reflection for students also sends the message that educators are not necessarily all-knowing, and that the development of knowledge is far from static (King & Kitchener, 1994; Pavelich & Moore, 1996) This is another example of reflection-in-action (Schön, 1987).

Educators have a responsibility for their students' development of higher-level learning cognitive skills, including reflection (Biggs, 1999; Biggs & Tang, 2011). To be effective, learning outcomes that incorporate reflection need to be aligned with course content and context, as well as with assessment, as a way to operationalize and measure the specific types of higher-level learning that all students should exhibit (Biggs, 1999; Biggs & Tang, 2011).

Educators need to retrieve knowledge that arises from prior experiences and contexts to better serve their current students, which they often accomplish with reflection (Hatton & Smith, 1995). They also need to identify what works, what does not work, and why. However, common barriers to the use of reflection were identified by Hatton and Smith (1995) as a disregard for its value in teaching, paradigms about teaching that discourage reflection, a lack of time and opportunity to reflect, and a sense of vulnerability about exposing one's innermost thoughts. In addition, all students and educators need a supportive environment to encourage both the efficacy and willingness to use reflective discoveries to confront long-standing assumptions and modify or discard them, as necessary (Mezirow, 2000). By eliminating these burdens to learning, students and educators can better use reflective learning strategies to attain learning that lasts.

2.4.4 Reflection Studies in an Engineering Context

Reflection provides a valuable way for engineering students to enhance their intellectual development, which requires them to consider their knowledge in both its essence and its limitations. These students also need to be able to apply their knowledge in alternative contexts because the same knowledge may be useful in upper-level college courses or in the workplace.

When engineering students use reflection as part of their learning strategies, they are using an intentional form of thinking that generates meaning (Turns, Sattler, Yasuhara, Bordford-Parnell & Atman, 2014).

A relatively early study in reflection for the formation of conceptual frameworks arising from prior knowledge showed similarities between first year engineering and non-engineering students at both the University of Pittsburgh and Carnegie Mellon University (Atman & Nair, 1996). In this study, reflection was shown to enhance the formation of a conceptual framework for the role of technology in society. First-year engineering and non-engineering students alike may have deep-seated beliefs about technology, which may or may not be refuted by evidence. The transfer of these beliefs to a different context may refute them or reinforce them. However, the value of reflection in acquiring and developing engineering knowledge in these and other applications has only been recognized and promoted in engineering education within the last 20 years, largely by Atman, et al. (2000); Adams, Turns and Atman (2003); and Turns, et al. (2014).

Engineering students need time to think about what they have learned because reflection takes time to develop as a learning strategy through multiple iterations of deep thought, scrutiny, and comparison with prior knowledge. However, too many engineering curricula resemble a "forced march" because of their fast-paced content (Chachra, 2013). The importance of time to reflect is often disregarded in these fast-paced courses because of the rush to cover ever more content superficially, rather than a few topics thoroughly. Time to reflect and synthesize knowledge is also important because the relationships among elements of knowledge within a course or within a curriculum are not often obvious at first glance. This rationale provided further evidence that reflection should be recognized as a useful learning strategy in engineering and that it should be given sufficient time to develop.

Two studies published in 2003 with first-year and upper-level engineering students identified the role of reflection as a learning strategy by conducting problem-based learning exercises (Adams, Turns & Atman, 2003; Atman, Turns, Cardella & Adams, 2003). In the Adams, Turns, and Atman study, the participants were interviewed and recorded as they solved a design problem. The study was repeated by Atman, Turns, Cardella, and Adams, but the second study employed verbal protocol analysis to record narratives by the participants as they solved a design problem without the researchers present (Atman et al., 2003). Results revealed relationships among reflection, metacognition, and motivation in both types of recorded narrative data as well as evidence that the participants had exhibited reflective practitioner behavior, as established by Schön's reflective practitioner theory (Schön, 1983, 1987). The results also led to recommendations for the guidance of students toward effective design practice, based on Schön's theory and its application to the study design.

An Australian study in 2010 used reflective writing in a senior level mechanical engineering course to promote the formation of professional identity, and tied this to ownership of learning (Reidsema, Goldsmith & Mort, 2010). A critical first step was students' recognition of their own limitations in knowledge, followed by a willingness to own their learning and develop intellectual rigor. The attribute of intellectual rigor was found to be necessary for new engineers to identify with the professional and intellectual community that they would soon enter. This ownership of learning ultimately relates to Biggs' two questions that drive the choices and implementation of learning strategies (Biggs, 1988):

- What do I want to get out of this? (i.e., the product of study)
- How do I get there? (i.e., the process of studying)

Academic engagement and the ownership of learning can also be promoted when engineering faculty realize that they can influence their students through more than just their explicit teaching activities when they employ a "reflective teaching practice" (Walther and Sochacka, 2011). These faculty should be aware of their overall image, as seen by their students, as students use their impressions of faculty to help them develop professional competence in both cognitive and non-cognitive ways, thereby fostering an identity with the engineering profession. This identity facilitates academic engagement with engineering knowledge (Chen, Lattuca & Hamilton, 2008).

2.4.5 Reflection for Knowledge Transfer and Retrieval

It is the purpose of institutions of higher education to promote and transfer learning, which includes not only specific knowledge but also skills and attitudes that facilitate the retrieval of knowledge for use in alternative contexts (Halpern & Hakel, 2003). The retrieval of knowledge also involves practice in self-testing, knowing where to seek necessary information, and/or integrating or reconciling new concepts with prior knowledge, all of which are learning strategies. Therefore, these learning strategies serve as learning-process-enabling skills, which are no less important than specific technical skills in technical subjects and remain valuable components in the "engineer's toolbox" (Sinreich, Gopher, Ben-Barak, Marmor & Lahat, 2005).

Engineering students also need to be able to apply their knowledge to alternative contexts because the same knowledge may be necessary in upper-level courses or in the workplace. Each of these scenarios involves knowledge transfer, which can be gained through both reflection and the organization of knowledge. By treating course content as a network of interconnecting relationships to be discovered and explored through self-questioning and self-monitoring for comprehension and understanding, these learning strategies are both metacognitive and reflective and result in sustainable learning for retention and transfer (Cunningham et al., 2017; Halpern, 1998; Halpern & Hakel, 2003; Hartwig & Dunlosky, 2012). The former provides the process for the search for meaning, while the latter reveals meaning. The student who plans, studies, and then evaluates their approach to learning may reflect on what else needs to be done, use reflection as a metacognitive tool for how they are doing it, and self-evaluate how effective their strategies were for achieving their goals for learning.

Meaning, which is often gained through reflection, is essential for knowledge retention and transfer (Floyd et al., 2009; Ganz & Ganz, 1990; Karpicke, 2009). Learning strategies help students to gain knowledge while reflection enables them to recognize its broader implications by viewing it in a "big picture" and employ the more flexible thinking processes that produce original and creative thought (Dirkes, 1985; Halpern & Hakel, 2003). Organizing one's knowledge in this way also enhances learning when students develop deep and meaningful knowledge structures as mental models (Ambrose, et. al., 2010).

The reflective student facilitates knowledge transfer and retrieval when they ask themselves, "Where have I seen this before?" as a key to the retrieval of accumulated knowledge for use in future courses or professions (Halpern & Hakel, 2003). Reflection for knowledge retrieval is further illustrated by reflection-in-action (Schön, 1983, 1987), the Kember reflection model (Kember et al., 2000), and by the aforementioned 2010 Australian study (Reidsema et al., 2010).

A student may remember a fact or skill more easily when it is linked to other facts or skills in their memory. This can be accomplished more often through the "deep" than by the "surface" learning approach (Biggs, 1988).

2.5 Research Methods to Explore Learning Approaches and Strategies with Reflection

The majority of prior studies that explored learning approaches, learning strategies, and the role of reflection that I found generally involved quantitative methods, such as surveys, questionnaires, and experiments under controlled conditions, often accompanied by statistical analysis. However, qualitative methods were used to gather and analyze written responses and journals, interview transcripts, and think-aloud protocols, either alone or in conjunction with the development of surveys or questionnaires.

2.5.1 Research Methods to Explore Learning Approaches and Strategies

A summary of prior methods to explore learning approaches and strategies is shown in Table 2.5, which contains a chronological listing of the data collection and analysis methods informing my current study and consists of fifteen quantitative, three qualitative, and two mixed-methods studies. The quantitative studies included the collection and analysis of historical data in addition to surveys or inventories, while the qualitative methods consisted of written experimental data followed by coding, think-aloud protocols, and coded observations of study behavior.

Even though the earliest study listed, that by Marton and Säljö (1976), involved coding for evidence of "surface" vs. "deep" learning, their data collection method carefully controlled the conditions in which the data were collected by pre-selecting passages of text and employing a control group as well as an experimental group and comparing the results. While any research study requires boundaries in order to be feasible, sometimes a preferred data collection method may require a protocol that would ordinarily be used in a quantitative rather than a qualitative study.

The Biggs (1979) and Baldwin and Koh (2012) studies involves a combination of quantitative and qualitative methods, although Biggs' use of his SOLO taxonomy could be considered as a tabulation or scoring method rather than coding. However, there was more individual judgment involved in Biggs' scoring method than in the tabulation of survey data gathered by administering the SPQ, for example. Using a more recognizable mixed-methods protocol, Baldwin and Koh (2012) first collected and evaluated written essays and scored them using qualitative-like judgments, and then tested the scores from two groups of participants for statistical significance.

In the remaining qualitative studies, by Douglass and Morris (2014) and McCord and Matusovich (2019), the former conducted focus group interviews and then coded their data through the grounded theory method, both of which are solidly recognized as qualitative methods. Instead of focus groups, McCord and Matusovich relied on direct observation of study groups followed by semi-structured individual interviews, and also used coding based on a previously established framework.

Many of the quantitative studies involved the administration of surveys or inventories of common learning strategies, student engagement, and/or self-efficacy, followed by statistical analysis for significance or, more commonly, correlation among the variables. One notable variation in the collection of data was the pair of studies by the Allen groups (Allen et al., 2008; Allen & Robbins, 2008), whose focus was on persistence in one's initial college major. One of the studies included a Student Readiness Inventory, along with data from participants' academic records, to compare the rate of persistence in a particular major with initial vocational interest, numeric evidence of both high school academic preparation and first-year academic performance. The Allen studies also included descriptive statistics and correlational analysis.

Experimental studies were also popular among the researchers in this summary, although the analysis methods differed markedly from those of Marton and Säljö (1976). Veenman and Verheij (2003) asked their participants to use a think-aloud protocol to develop a formula for an explosive mixture, gave them technical data about the available components, and then asked them to construct two mathematical models based on hypothetical situations. The narratives were transcribed, but instead of being coded, they were scored against scales for each study variable. The scores were subjected to statistical analysis with the ultimate goal being the determination of overall intelligence based on metacognitive skillfulness. Later, Kornell and Son (2009) conducted experiments in word recall to investigate participants' beliefs about the value of self-testing.

2.5.2 Research Methods to Explore the Learning Value of Reflection

This section contains a summary of studies using both quantitative and qualitative research methods to identify learning approaches and strategies. While Table 2.5 contains a number of studies in which self-regulating, metacognitive learning strategies were clearly recognized as facilitators of learning, Table 2.6, attached on page 72, contains studies in which reflection exerts a major role in the selection of learning approaches and strategies.

2.5.2.1 Prior Studies in Reflection for Learning Approaches and Strategies

Table 2.6 contains corresponding and collaborative studies by Biggs (Biggs, 1988; Biggs et al., 2001) and by the Kember groups (Kember, 1999; Kember, Wong & Leung, 1999; Kember, et al., 2000; Kember & Leung, 1998; Leung & Kember, 2003), along with follow-on studies by Phan (2008, 2009), Floyd, Harrington and Santiago (2009), and others. These remaining studies extended the application of Biggs' study processes questionnaire and Kember's reflection questionnaire to the further exploration of reflection as it relates to beliefs about learning, student engagement, metacognitive assessment, and self-monitoring.

The studies in Table 2.6 were published during the 1988-2017 time period and trace the evolution of studies in approaches to learning, learning strategies and reflection through the work of Biggs and Kember, and others whose work is based on studies by these two researchers. The predominant data collection method found among these studies is one or more survey-type instruments administered to populations of 50+ students, although a few mixed-methods studies combined the coding of written responses with paired sample t-tests, reliability testing, and correlational analysis.

The survey instruments in Table 2.6 include Biggs' study processes questionnaire (Biggs, 1988; Biggs et al., 2001), Kember's reflection questionnaire (Kember et al., 2000; Leung & Kember, 2003), Meyer's reflection on learning inventory (Meyer, et. al., 2012; Meyer, Knight, Callaghan & Baldock, 2014, 2015), Sobral's reflection in learning scale (Kalk, Luik, Taimalu & Täht, 2014), and the Watson-Glaser critical thinking appraisal (Ghanizadeh, 2017). Analytical methods for the data obtained in these studies included exploratory and confirmatory factor analysis, statistical significance, correlation, and goodness-of-fit for proposed models. At least two studies contained the inclusion of questions from several existing instruments in new questionnaires (Biggs et al., 2001; Floyd, et al., 2009; Phan, 2009).

By contrast, only five of the fifteen studies in Table 2.6 involved qualitative methods for data collection and analysis (Kember, 1999; Kember et al., 1999; Meyer et al., 2012; Meyer et al., 2014, 2015), and from only two groups of investigators.

The qualitative data were analyzed by coding, but only one level of coding was reported. Most of the data were in the form of written responses collected from journals or from open-ended questions that were included with questionnaires. However, one study used semi-structured interviews to gather students' perceptions about motivation, as part of a study that included testing of the reliability of Biggs' study process questionnaire (Kember, et al.,1999). These studies led to the development of Kember's four-stage model of reflective thinking: Habitual Action, Understanding, Reflection, and Critical Reflection, as well as the Kember reflection questionnaire (Kember, 1999; Kember et al., 2000; Kember et al., 2008).

Table 2.7, attached on page 74, contains a summary of additional studies in learning strategies, including reflection, along with descriptions of their research methods. Data were collected through written journals or other prompted writing exercises in all of the studies. In addition, one 2010 study combined written responses with a test of scientific reasoning ability, observation of student behavior during design experiments, and course exam scores (Etkina et al., 2010), while another collected reflection data after a metacognitive intervention (Cunningham et al., 2017). The majority of studies used qualitative analytical methods, such as coding, scoring against a rubric, thematic analysis, and a systemic functional grammar approach. However, two studies also incorporated quantitative analytical methods, such as descriptive statistics and tests for significance, validity, and reliability (Etkina et al., 2010; van Velzen, 2017).

2.5.2.2 Flexibility of the Kember Reflection Model for This Study

When a phenomenon is described as a series of stages, it is logical to imagine that a person progresses linearly through these stages, as though each succeeding stage builds on the previous one. When students regard the nature of knowledge and develop their own epistemology, several models have been constructed as progressions from, for example, knowledge as absolute to knowledge as contextual and conditional, and therefore inherently uncertain (King & Kitchener, 1994; Pavelich & Moore, 1996; Perry, 1999). Since the nature of knowledge is often revealed through reflection, several researchers have described the use of reflection as a set of stages, where the more desirable stages lead to the regard for knowledge as dynamic, context-dependent, and not absolutely certain (Hatton & Smith, 1995; Moon, 2004; Sparks-Langer et al., 1990). Even the Kember model was constructed as a set of four stages, in which the latter stages exhibit greater amounts of reflection than the earlier stages and were even linked to Biggs' deep approach to learning, which is another commendable condition for students to attain (Kember et al., 2000, 2008; Leung & Kember, 2003).

Based on the study results, I found that the first-year engineering students in this study employed learning strategies that arose from several stages of the Kember model within the same course, and among their courses. These results contradicted my original premise that certain students would agree with using the strategies for a particular Kember stage to the exclusion of other stages in any single course. My premise also caused me to construct the reflection-related survey questions to prompt for individual courses rather than for each student's use of reflective learning strategies over all of their courses, as prior studies had reported (Ghanizadeh, 2017; Kalk et al., 2014; Kember et al., 2000, 2008; Meyer, 2004).

Therefore, the Kember model, and possibly similar reflection models, should not be considered as a progression through the stages, but a collection of stages that could be combined in various ways depending on the context to which they are applied. While there may be similarities between models for reflection and models for intellectual development, the fact remains that first-year engineering students in this study choose different strategies for different courses and contexts within and among their courses. Their choices exemplified my conclusion that first-year engineering students use reflective learning strategies in non-linear combinations.

2.5 Chapter Summary

The identification of the impacts and consequences of academic disengagement informed my study by providing not only background information to establish the importance of attempting to mitigate it during and after the first year of college for engineering students, but also by underscoring the importance of exploring learning and approaches and strategies to a greater extent than reported in previous studies. Since relatively few of these studies have involved first-year engineering students, it was timely to adopt two widely accepted conceptual frameworks for this inquiry, drawn from the constructivist worldview, and to describe more fully what is meant by "learning approaches and strategies." In addition, the value of reflection as a set of learning strategies was found to have provided value to the learning experience by revealing the meaning behind what was being learned. The insights described in this chapter further informed the formation of my research methods, which are described in detail in the next chapter.

Table 2.5: Purpose, Data Collection, and Data Analysis Methods for Selected Studies that Involve Learning Strategies

Year	Author(s)	Study Purpose	Data Collection Method(s)	Data Analysis Method(s)
1976	Marton and Säljö	Identified different levels of study processes and strategies, based on levels of comprehension	Undergraduate student participants read samples of prose and answered questions about content and meaning.	Responses were coded according to the level of processing of the information in the passages: "surface," focused on content, and "deep," focused on meaning.
1978	Biggs	Establish a model for study processes based on the study processes questionnaire (SPQ).	SPQ administered to undergraduate students after they had completed several course-related assessments.	Statistical methods on responses from a random sample of the population; factor analysis on demographically segmented samples of responses.
1979	Biggs	Relate study processes to the quality of learning by expanding on the work of Marton and Säljö (1976).	Modified SPQ administered to undergraduate students, along with two written assignments containing short essays and questions.	SPQ questions linked to three previously identified study process/approaches to learning; each participant labeled with preferred study process; Structure of Observed Learning Outcome (SOLO) Taxonomy used to measure quality of learning.
1984	Ryan	Identify types of reading comprehension criteria used by college students; relate them to students' conceptions of knowledge, and grades.	1. 50-item survey administered to undergraduates (59% first-year) about conceptions of knowledge. 2. Essay question about how student assessed their reading comprehension.	1. Survey was based on Perry (1968) questions correlated to dualistic vs. relativistic epistemologies. 2. Reading comprehension assessment compared to course grades.
2002	Veenman & Verheij	Determine whether "metacognitive skillfulness" is a function of intelligence as it relates to learning.	1. First-year students in an experiment where each developed a formula, using a think-aloud protocol. 2. Each participant developed mathematical models for two problems, thinking aloud as they wrote.	Participants' narratives were transcribed, then scored from 0-4 using subscales for orientation activities, orderliness, accuracy, evaluation, and elaboration. Participant scores were the means of their subscale scores for each of the two tasks. Principal component analysis, descriptive statistics, and correlational analysis were also applied to the data.
2003	Diseth & Martinsen	Explore and analyze the relationships among approaches to learning, cognitive style, motives, and grades.	One section of the ASSIST inventory administered to undergraduate students.	Descriptive statistics, factor analysis, and principal component analysis applied to the survey results.
2005	Cleveland-Innes & Emes	Determine the impact of social and academic interaction on approaches to learning.	Administered three surveys to undergraduates over an academic year: original survey about student backgrounds and learning contexts, study processes questionnaire, and student experience (social interaction) questionnaire.	Data reduction by combining correlated scales and weighting scores; individual survey scores compared to time of year when survey was administered; factor analysis to computer zero-order correlations among variables.
2006	Gore	Address the incremental validity of relating academic self-efficacy to predict academic performance.	1. Administered CSEI and ASC self-efficacy inventories to first-year undergraduates in an orientation course;	Both studies: descriptive statistics, correlational analysis, linear regression.

			compiled participants' ACT composite scores. 2. Administered Student Readiness Inventory (SRI) to first-year students randomly selected from multiple institutions; compiled participants' ACT scores.	
2008	Allen & Robbins	Predict persistence in college major based on vocational interest, academic preparation, and first-year academic performance.	Compiled ACT-provided data, first-year GPA, first-year choice of major, and third-year choice of major for undergraduates at 25 institutions. ACT data included ACT scores, high school GPA, vocational interest, and demographic data.	Collated vocational interest data into CIP codes of groups containing similar majors; calculated first year to third year persistence rates for each major group and developed models for predicting major persistence based on the input variables; correlated the predictors of interest with first-year GPA and major persistence.
2008	Allen, Robbins, Casillas & Oh	Relate motivation and social connectedness to persistence in college major directly and/or indirectly; test the effect of academic performance, motivation, and social connectedness on retention in or transfer from first-year major, both within and between institutions.	Administered SRI survey to first-year students at multiple institutions; collected first-year GPA, enrollment data, and demographic data for rising third-year students.	Descriptive statistics; applied data to the previously developed models; correlational analysis among the study variables; calculated enrollment status as stayed vs. dropped or transferred vs. dropped.
2009	Karpicke, Butler & Roediger	Determine how often students practice recall or self-testing in a real-world academic setting.	Administered an in-house survey to undergraduate students about their study strategies for exams, after participating in learning and memory experiments.	Calculated percentage of responses for each possible response to each forced-response survey question; descriptions, numbers, and percentage of responses in a free-response question.
2009	Karpicke	Explored the interrelationships among retrieval practice effects, monitoring of learning, and decisions to practice learning retrieval.	Experiment in recalling bilingual word pairs where participants could choose to self-test or continue studying, as a measure of their judgment of learning.	Descriptive statistics based on calculation of percentage responses for each option of the judgment of learning.
2009	Downing	Explored the relationships between metacognitive development and GPA.	Administered LASSI survey longitudinally to undergraduate students at three stages: entry, interim and exit	ANOVA to determine differences in metacognitive development among high, medium, and low achievers. Metacognitive development variables: anxiety, motivation, skill, will, and selecting main ideas.
2009	Kornell & Son	Investigated beliefs about, and effectiveness of, self-testing on learning	1. Experiment: participants were asked to judge the effectiveness of testing vs. studying when learning bilingual word pairs.	Descriptive statistics on the results to demonstrate significance among rates of accuracy for early self-testing vs. repeated studying followed by testing, as well

			2. Experiment: participants were asked to choose between studying a bilingual word pair longer, or being tested on it, with multiple iterations of studying and testing offered.	as compatibility between metacognitive beliefs and study choices.
2012	Baldwin & Koh	Determined how teaching practices can enhance student engagement in large first-year survey courses.	Graded essay assignment in two parts: a. Outline and annotated reference list—graded and returned with feedback. b. Final essay.	Average scores for all participants on both assignments were compared to those for a control group from the previous year; differences tested for statistical significance.
2012	Hartwig & Dunlosky	Explored the relationship between choices of learning strategies and GPA, with a focus on self-testing and scheduling study time.	Administered a learning strategies survey adapted from one used by Kornell and Bjork (2007), to undergraduate students (78% first-year)	Compared results to those of Kornell and Bjork (2007), where applicable; segregated responses by GPA group and reported percentage of responses to questions about self-testing and scheduling by GPA group
2014	Douglass & Morris	Investigated students' perspectives on self-directed learning	Eight focus group interviews containing six questions each, with undergraduate participants and by peer facilitators.	Interview transcripts double-coded in two iterations, using a grounded theory approach attributed to Strauss and Corbin (1998)
2014	Brint & Cantwell	Measured and analyzed characteristics of academically disengaged students, including study behaviors	Administered Undergraduate Experiences Survey to students at nine campuses in state university system (response rate 33–53%)	Principle components factor analysis and logistic regression to identify location and attributes of disengaged populations
2016	Morehead, Rhodes & DeLozier	Investigated students' and instructors' awareness of learning strategies and judgments about the efficacy of strategies for specific learning situations.	Administered a learning strategies inventory adapted from those by Kornell and Bjork (2007) and Hartwig and Dunlosky (2012) to undergraduate students and instructors	Compared percentage response results to those of prior researchers; descriptive statistics for student and instructor groups for similarities and discrepancies.
2019	McCord & Matusovich	Develop a method to explore metacognitive development underlying choices of learning strategies in study groups	Repeated observations of study behaviors of undergraduate students in three self-selected study groups, followed by individual interviews and member checking of the data.	Coded episodes of study behavior using a metacognitive engagement framework by Whitebread (2009), resulting in a generalizable coding method.

Table 2.6: Purpose, Data Collection, and Data Analysis Methods for Biggs', Kember's, and Subsequent Studies with Learning Strategies and Reflection

Year	Author(s)	Study Purpose	Data Collection Method	Data Analysis Method
1988	Biggs	Explored metacognitive awareness through two intervention studies using the study process questionnaire (SPQ).	SPQ administered to two cohorts of at-risk students already taking a study skills course.	SPQ scores analyzed using ANOVA.
1998	Kember & Leung	Determined the reliability of SPQ.	Administered SPQ to university students.	Confirmatory factor analysis; reliability.
1999	Kember	Determined depth of reflective thinking by university students.	Written journals.	Coding into seven categories based on framework by Mezirow (1991).
1999	Kember, Wong & Leung	1. Students' perceptions of motivation in courses. 2. Reliability of the SPQ (repeat Kember & Leung (1998) above).	1. 55 semi-structured interviews. 2. Same as Kember & Leung (1998) above.	1. Coding for "surface" vs. "deep" learning approaches. 2. Confirmatory factor analysis.
2000	Kember, et al.	Developed a questionnaire to measure reflective thinking (reflection questionnaire (RQ)).	Administered RQ to health sciences students.	Confirmatory factor analysis; statistical significance (quantitative).
2001	Biggs, Kember & Leung	Revised the SPQ into a shorter two-factor version measuring "surface" and "deep" learning.	Administered revised SPQ to university students from various departments.	Confirmatory factor analysis, reliability, statistical significance.
2003	Leung & Kember	Detected an association between approaches to learning and reflective thinking.	Administered SPQ and RQ to undergraduate health sciences students.	Confirmatory factor analysis, reliability, statistical significance.
2008	Phan	Tested models for epistemological beliefs, approaches to learning, reflective thinking, and academic performance.	Administered RQ, revised SPQ, and Schommer epistemological questionnaire to first-year and second-year students over 12 months.	Descriptive statistics, reliability, and statistical significance, resulting in a new joint model.
2009	Phan	Tested a conceptual model relating "deep" learning strategies, reflection, critical thinking, effort, performance-approach goals, and mastery.	Administered an instrument containing questions from four other instruments, including the RQ; written responses from in-class tests and writing assignments containing open-ended questions.	Descriptive statistics, reliability, and correlation, resulting in a new joint model.
2009	Floyd, Harrington & Santiago	Study the relationships among perceived course value, student engagement, "surface" learning strategies, "deep" learning strategies.	Administered an instrument containing questions from four other instruments, including the revised SPQ, to students in information technology.	Descriptive statistics and correlation.

2012	Meyer, Knight, Baldock, Kizil, O'Moore & Callaghan	Distinguish variations in learning behavior among undergraduate students with different ages and disciplines.	Administered Meyer's Reflection on Learning Inventory (RoLI) to first, second, and third year students; one subgroup provided written reflective responses about the effect of the RoLi on their own learning behavior.	Exploratory factor analysis on the RoLi numeric data; coding for emerging themes among the responses.
2014	Kalk, Luik, Taimalu & Täht	Explore validity and reliability through internal consistency and factor structure of two instruments to measure reflection.	Administered Kember Reflection Questionnaire and Reflection in Learning Scale (Sobral, 2001) to student and practicing teachers.	Confirmatory factor analysis, goodness-of-fit, reliability.
2014	Meyer, Knight, Callaghan & Baldock	Explore metacognitive assessment activities for variations in understanding of threshold concepts, based on Biggs' SOLO taxonomy.	Prompted third year civil engineering students to answer an open-ended question, grade answers provided by faculty, then grade their own answer, and answer reflective questions.	Paired samples t-test for comparison of grades between students and faculty; coding of reflective responses.
2015	Meyer, Knight, Callaghan & Baldock	Identify threshold concepts as a focus for a metalearning activity (involves metacognition and approaches to learning).	Administered Meyer's RoLI to third-year civil engineering students twice during a semester. Students also wrote responses to open-ended reflective questions.	Written responses coded using a constant comparative method. RoLI data analyzed for reliability and inter-observable correlations
2017	Ghanizadeh	Explored relationships among reflective and critical thinking and evidence of self-monitoring (a learning strategy).	Administered the Kember reflection questionnaire and the Watson-Glaser critical thinking appraisal to university students; students self-reported their GPA with their responses.	Descriptive statistics and correlation.

Table 2.7: Purpose, Data Collection and Data Analysis for Additional Studies Involving Learning Strategies and Reflection

Year	Author(s)	Study Purpose	Data Collection Method(s)	Data Analysis Method(s)
2004	Ash & Clayton	Developed and demonstrated a model for reflection and applied it to service learning experiences to enhance learning.	Written journals containing responses to four prompts: 1. What did I learn? 2. How did I learn it? 3. Why does this learning matter? 4. In what ways will I use this learning?	Applied rubrics based on critical thinking standards and the application of description, analysis, and articulation. Text was coded for indications of feelings, assumptions, strengths, weaknesses, traits, skills, and identity.
2005	Ash, Clayton & Atkinson	Employed reflection products to assess and improve student learning in a service learning context.	Written journals containing responses to the four questions listed above. Collected both draft and final versions of these journals.	Both draft and final versions scored against rubrics previously developed in above study, with formative assessment feedback supplied to participants prior to writing final journals.
2010	Etkina, Karelina, Ruibal-Villasenor, Rosengrant, Jordan & Hmelo-Silver	Investigated whether experimental design in a science learning environment promoted development of scientific abilities in an introductory physics through interpretive knowing.	Lawson's test of scientific reasoning ability administered to all participants initially. Selected lab sections then performed design experiments and answered reflection-related questions, while other sections performed non-design experiments without answering reflection-related questions. Student behavior observed in both types of sections. Course exam scores also collected and compiled.	Results from Lawson's test analyzed for significance between control and experimental groups. Student behavior data was coded according to three themes: sense-making, logistics and off-task. Student and instructor behavior were coded separately. Coded reports were scored with a rubric also used by the participants for self-assessment. Results compared to participants' exam scores.
2010	Reidsma, Goldsmith & Mort	Explored reflective writing to develop lifelong learning skills and the formation of professional identity in a senior level mechanical engineering design course.	Four written reflective essays, equally spaced during the course	Thematic analysis approach for key themes by three different researchers, then concordance analysis to clarify and validate the themes, and to detect patterns of meaning. Agency was then detected using a systemic functional grammar approach.
2010	Hubbs and Brand	Proposed a method for guiding students to write meaningful reflective journals by providing a method to analyze journal entries for appropriate feedback to students.	Collected reflective journals from graduate -level participants in pre-professional human services education courses.	Categorized each journal statement as content- vs. process-focused; process includes participants' thoughts, feelings, attitudes and/or beliefs. Formed a judgment for each type of statement in terms of superficial vs. analytical reflection, using a 2x2 matrix with content and process on a virtual x-axis, and degree of reflection on a virtual y-axis.
2012	Wald, Borkan, Taylor, Anthony & Reis	Proposed an analytical tool for reflective writing in medical education, intended to provide	Prompted reflective writing exercises from two medical school courses.	Used an analytical instructional rubric derived from theoretical models of reflection coupled with assessment methods in medical education.

		more effective and meaningful written feedback.		Rubric criteria included writing quality, presence, description of conflict, attending to emotions, analysis and meaning making, and attention to the prompt.
2017	van Velzen	Explored the relationship between self-induced reflection and the process of learning.	1. Short written responses to three prompts by high school student participants: a. Consider how well you have understood the given material. b. Consider why the material is relevant to you. c. How could you improve your learning of the material? 2. Administered two questionnaires to measure metacognitive knowledge.	1. Responses categorized according to an existing three-stage hierarchy for learning and personal development. 2. Descriptive statistics, nomological validity of participants' understanding of the learning process, principal component analysis, reliability measures.
2017	Cunningham, Matusovich, Hunter, Williams & Bhaduri	Developed metacognitive indicators for instructors to assess students' metacognitive processes, using an indicator rubric.	Responses to reflection questions prompted by metacognition-related intervention activities; written assignment following the intervention activities.	Rubric based on six modules contained in the intervention activities. A priori coding of the responses, with rankings of high, medium, and low for extent of response, followed by Natural Language Processing textual data analytics, which is a statistical method.

3.0 Methods

3.1 Introduction

This chapter contains the methods used to explore the learning approaches and strategies of first-year engineering students, how they might use different strategies for different courses, and the role of reflection as part of their learning approaches and strategies. These methods provided data to address the problem of academic disengagement among rising sophomore students, which can be mitigated by meaningful academic preparation during the first year (Downing, 2009; Gore, 2006). My study was intended to inform educators as to how they can enhance their students' current approaches to learning through guidance in the use of "best practices" in learning strategies among the group of first-year engineering student who participated in both surveys and interviews.

The methods in this chapter contributed to the exploration of the following research question and sub-questions:

- How do first-year engineering students describe their learning approaches and strategies?
    - How do first-year engineering students customize their learning approaches and strategies among their courses?
    - How do first-year engineering students employ reflection as part of their learning strategies?

I chose the constructivist worldview as my research framework because it was grounded by the realization that knowledge is often constructed not in isolation, but through interaction and negotiation between and among individuals and their environment (Ponterotto, 2005; Vygotsky, 1978). Thus, the emerging data was constructed not from a central source of truth, but from the participants' experiences (Ponterotto, 2005).

3.2 Research Design

While the overall problem of academic disengagement during the sophomore year affects students in a wide variety of disciplines, a necessary first step in mitigating its effects in engineering was to explore what first-year engineering students were already doing when they study. I formed my research question on the basis that this was an underexplored area of research (see Section 1.2). This question was influenced by the work of Biggs (1988, 1996, 1999) in the identification and description of learning approaches and strategies and by Kember, McKay, Sinclair, and Wong (2000) in the use of reflective learning strategies and how they could be characterized in four stages. My own prior studies involving reflection among first-year engineering students also informed this study (Van Tyne, 2015, 2018, 2019).

3.2.1 Conceptual Frameworks

The conceptual frameworks for this study also used a constructivist lens, for the practical reasons that what the student participants did should have greater importance than any edict of theory, and that students could improve their ability to deal with ill-defined societal problems by constructing their own knowledge through reflection (Biggs, 1999; Kember et al., 2000). Both Biggs and Kember mainly employed quantitative methods to collect and analyze data, such as Biggs' Study Processes Questionnaire and Kember's Reflection Questionnaire (Biggs, 1988; Biggs, et al., 2001).

Kember and Leung reported their critique of Biggs' Study Processes Questionnaire in 1998 (Kember & Leung, 1998) and developed their own Reflection Questionnaire (Kember et al., 2000) informed by qualitative studies using written journals (Kember (1999) and semi-structured interviews (Kember, et al.,1999). They later administered both the Biggs Study Processes Questionnaire and the Reflection Questionnaire to undergraduate students to identify relationships among approaches to learning and reflective thinking (Leung & Kember, 2003). However, the participants' class year was not specified in any of these studies.

I could not find evidence that Biggs conducted qualitative studies of approaches to learning. While Biggs' frameworks for "surface" and "deep" learning were undoubtedly influenced by his observations of student behavior in his classroom, these observations were not reported as part of his research results. In addition, the participants' class year was not specified in any of the available Biggs studies, so that it is not clear as to whether first-year students were involved.

Additional studies provided examples of learning strategies commonly used by undergraduate students in unspecified class years and without differentiation among the types of courses (Crede & Kuncel, 2008; Hartwig & Dunlosky, 2012; Karpicke et al., 2009; Kornell & Bjork, 2007; Morehead et al., 2016). All of these studies involved quantitative surveys or inventories of learning strategies. Only one of the aforementioned studies contained a free-response question that could have been qualitatively analyzed: "What kinds of strategies do you use when you are studying?" (Karpicke et al., 2009).

Overall, this group of studies provided a starting point for the exploration of learning strategies, but I wanted to learn more about choices of strategies among courses. Quantitative approaches, such as surveys, revealed general trends among largely unspecified populations and class years, which caused me to wonder about more specific aspects of student learning, especially among first-year engineering students. One trend did emerge that sounded familiar: choosing to pursue learning strategies "by triage" rather than through self-regulated learning

(Kornell & Bjork, 2007). This study also asserted that many students need guided practice in learning strategies in order to become self-regulated learners (Kornell & Bjork, 2007). First-year engineering courses provide a forum for such guided practice, but only when informed by what students already do.

The one study that employed a free-response question reported a list of eleven learning strategies and the relative frequency with which the participants used them (Karpicke et al., 2009). However, these responses were not described further and were not differentiated among the participants' courses (Karpicke et al., 2009). The study also focused attention on self-testing as its most important learning strategy (Karpicke et al., 2009). I expected that other learning strategies might be equally valuable to students, and this caused me to design my study to provide more complete information than I had found in prior studies.

3.2.2 My Choices of Research Methods

I chose both qualitative and quantitative methods in keeping with the dual theoretical frameworks of Biggs and Kember, who also used both types of methods in their joint and respective studies (Biggs et al., 2001; Kember, 1999; Kember et al., 1999, 2000). My methods included both surveys and interviews and were designed to elicit information about variations in the use of learning approaches and strategies among both technical and non-technical courses, as well as the ways in which students use reflection to reveal knowledge and what it means to them.

By focusing on engineering students at the first-year level, I applied the methods and results of prior research designs to a largely underexplored area of undergraduate student learning. Quantitative methods enabled me to collect data describing study methods and course contexts from a representative sample of this population, while qualitative methods enabled me to probe the details of students' decision-making in a small sample selected across a continuum of study approaches. Another reason to employ both quantitative and qualitative methods to collect and analyze data from first-year engineering students was to be able to answer my research question and sub-questions in their natural context—in this case, a first-year engineering program (Borrego, Douglas & Amelink, 2009; Creswell & Poth, 2018b).

Specifically, the combination of methods that I used can be described as an explanatory sequential design, which is formed of a mixed-methods design (Creswell & Plano Clark, 2011). Within this design, I collected one set of quantitative survey data, analyzed part of it to inform the selection of participants for interviews, collected the qualitative interview data, and then collected a second set of quantitative survey data from the same set of participants who had completed the first survey. I then analyzed both sets of survey data in depth and triangulated the survey data for the interviewees with their interview data. The definition of an explanatory sequential design implies that quantitative data collection and analysis end when the qualitative phase of exploration begins (Creswell & Plano Clark, 2011). However, I conducted the quantitative data collection step a second time in order to more thoroughly answer my research question and its sub-questions.

3.2.3 Study Protocol

My study protocol is described in Table 3.1 on the next page.

Table 3.1: Overall Research Plan and Results

Research Question	Data Collection Methods	Data Analysis Methods	Types of Results
How do first-year engineering students describe their learning approaches and strategies?	Eleven questions added to a department's End of Semester Survey in Fall 2020 and Spring 2021, respectively.	Summarize results within and among four types of courses, including median Likert scores and Interquartile Range values, along with a reconciliation to the Likert scale methodology.	Quantitative profiles of **Study Samples'** reflective learning approaches and strategies, including common and diverse strategies within and among courses.
	Fifteen semi-structured interviews, each containing seven standard questions and several follow-on questions.	*a priori*, pattern, and comparative coding of interview transcripts.	Qualitative and rich descriptions of learning approaches and strategies within and among courses, including the use of reflective learning strategies.

Data addressing both of my sub-questions were collected through the administration of specific survey questions about the use of learning strategies, including reflection, among technical and non-technical courses, to two **Study Samples** and a volunteer group of **Interviewees**. The composition and demographics of the **Study Sample** and **Interviewee** groups are described in Section 3.3. The relationships among learning approaches and learning strategies were developed through coding, as shown in Table 3.1. By combining findings from both sets of data, I addressed both the sub-questions and the overarching research question about learning approaches and strategies employed by first-year engineering students.

3.3 Population, Sample, and Participants

The first-year engineering courses in this study setting were taken by entering engineering students sequentially, in their first fall and spring semesters. Each course was described in our institution's undergraduate course catalog as follows:

- Foundations of Engineering I (ENGE 1215): data collection and analysis, engineering problem-solving, mathematical modeling, contemporary software tools, professional practices, and expectations (e.g. effective communication, working in teams, ethics), and the diversity of fields and majors within engineering.
- Foundations of Engineering II (ENGE 1216): data collection and analysis, engineering problem-solving, mathematical modeling, design, contemporary software tools, professional practices, and expectations (e.g. communication, teamwork, ethics).

Together, the sequence was intended to introduce students to the engineering profession by practicing a range of skillsets, as well as increasing awareness of the range of engineering career paths and the ways in which to pursue them.

The study setting is a Carnegie Classification R-1 research university in the eastern United States, with a total undergraduate student population of 30,020 as of October 2020, and a total undergraduate engineering enrollment of 9,358 (Virginia Tech Engineering, 2020). The Fall 2020 first-year engineering enrollment was 2,040 students, who had met the admissions requirements of 18 units of high school courses, distributed among English, mathematics, laboratory science, social science, and other academic and subjects (Office of Undergraduate Admissions, 2021). In addition, the 2019 entering class of first-year engineering students held a high school GPA of 4.14, and had submitted SAT scores averaging 707 in mathematics, 652 in reading, and 1350 overall (Virginia Tech College of Engineering, 2021).

3.3.1 Study Sample and Interviewee Selection

The **Study Sample** and **Interviewee** groups were drawn from the populations of ENGE 1215 and ENGE 1216 students as shown in Table 3.2 on the next page and Table 3.3 on page 85.

Table 3.2: Selection of the Study Sample, Fall 2020 and the Interviewees

Number	Description
2,040	**Fall Cohort**: those who completed ENGE 1215 End of Semester Survey, December 2020
1,223	Participants' data available through IRB #12-507 (**Study Sample Fall 2020,** 920 (75.2%) men, 300 (24.5%) women, and 4 (0.3%) gender-not-identified)
285	Participants who agreed to participate in interviews (**Interview Pool, Fall 2020**)
259	**Interview Volunteers** who were not enrolled in Spring 2021 ENGE 1216 sections that I taught (171 (66%) men and 88 (34%) women)
36	Interview volunteers selected for a range of learning approaches in ENGE 1215 (**Prospective Interviewees)**
15	**Interviewees** (a stratified sample)

Survey data from the 285 **Interview Volunteers** were isolated from the **Study Sample, Fall 2020** dataset; these participants became the **Interview Pool, Fall 2020**. Data from **Interview Pool, Fall 2020** members whose email addresses matched those of any of the students in my four sections of ENGE 1216 during the Spring 2021 semester were removed from this data set, and the remaining members became the **Interview Volunteers** dataset. The 259 **Interview Volunteers** contained 171 (66%) male and 88 (34%) female students.

Next, the **Interview Volunteers** were subdivided into groups based on one or more of five possible responses to the EOS survey question, "What is your purpose for studying in ENGE 1215?" The possible responses, and the apparent learning approaches that they represent, based on my understanding of learning approaches from the literature, were as follows:

1. Need to pass the course (surface approach)
2. Want to get an A in the course (surface-achieving approach)
3. Need to "do well" in the course to succeed in future courses (deep-achieving approach)
4. Am interested in the course material (deep approach)
5. Like to learn new things by studying them in detail (deep approach)

Within the **Interview Volunteers** group, 87 (33.6%) had indicated one or two of the responses listed above, while the remaining 172 (66.4%) had selected three or more responses. I applied a limit of two responses to the members of the Interview Volunteers group because there was likely to be a greater probability of response bias among these 172 participants than among the rest. This reason was based on my experience in working extensively with first-year students. This limitation is discussed further in Section 3.6.3.

Each of the remaining 87 participants was then labeled with an apparent learning approach, based on their responses to the purpose-for-studying question. I reconciled the two-response combinations of learning approaches as follows, in which I assigned short-term benefits to surface approaches, long-term benefits to deep approaches, and the attainment of grades to achieving approaches:

- Pass the course and get an A: surface-achieving
- Pass the course and do well for other courses: deep-achieving
- Get an A and do well for other courses: surface-achieving
- Get an A and interest in course material: deep-achieving
- Get an A and like to learn new things: deep-achieving
- Do well for other courses and interest: deep-achieving
- Pass the course and interest: deep
- Interest and like to learn new things: deep

I selected the 36 **Prospective Interviewees** from the group of 87 while maintaining a gender ratio of two men to one woman, with representation of all of the apparent learning approaches. Gender and apparent learning approach served as stratifying factors for this selection, as well as for the eventual selection of the **Interviewees**. A total of twenty-four

Prospective Interviewees were contacted and invited to participate in an interview, of which fifteen responded positively, for a total of ten men and five women **Interviewees**.

The distribution of participants who completed the ENGE 1216 End Semester Survey and their relationship to the **Study Sample, Spring 2021** and the Interviewees in shown in Table 3.3.

Table 3.3: Selection of the Study Sample, Spring 2021, and Relationship to Interviewees

Number	Description
2,000	**Spring Cohort**: those who completed ENGE 1216 End of Semester Survey, May 2021
1,224	Participants' data available through IRB #12-507 (**Study Sample Spring 2021,** 905 (74%) men, 306 (25%) women, and 12 (1%) gender-not-identified)
263	Participants who agreed to participate in interviews (**Interview Pool, Spring 2021**)
14	**Interviewees** from the original cohort who completed ENGE 1216 End of Semester Survey, May 2021 and agreed to a follow-up interview

Each of the **Study Samples** represented approximately 59% of the study population. This low number was due to the fact that first-year engineering students were offered a short survey asking for their consent or non-consent to allow their coursework to be used as research data, and they could have consented, not consented, or not completed the survey. Therefore, data from students who did not complete the survey were also excluded from access for research purposes, in addition to data from students who did not consent.

At a 95% confidence level, this sample size of 1,223 yielded a confidence interval, or margin of error, of 1.79, meaning that, if 50% of the sample participants chose a specific response on a survey, then between 48.21% and 51.79% of the population would choose the same response (The Survey System, 2012). This also meant that the larger the sample, the greater the probability that its data were representative of the population

3.3.2 Interviewees' Representation of Study Sample

It was important to consider how well the **Interviewees** represented the **Study Sample** from which they were drawn, so that their results would more closely indicate the variety of learning approaches and strategies identified by Biggs. The **Interviewees** were selected as a stratified sample of the **Interview Pool** in order to improve representation (Krathwohl, 2009a). Stratification was based on gender and response to a survey question about the purpose of studying in ENGE 1215.

Figures 3.1 and 3.2, on the next page, illustrate the male-female gender distribution for the **Interviewees**, **Interview Pool,** and **Study Samples.**

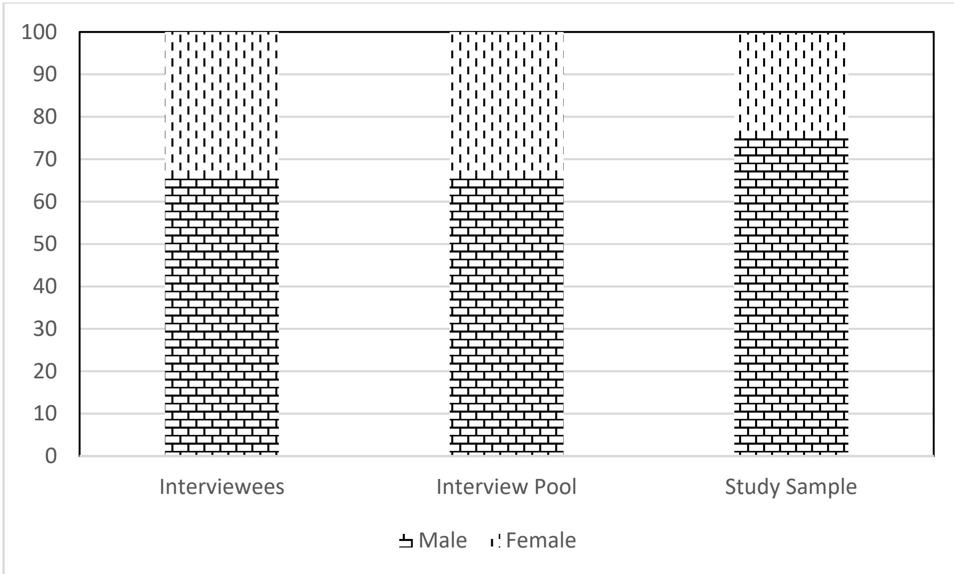

Figure 3.1: Percentages of Male and Female Students, Fall 2020

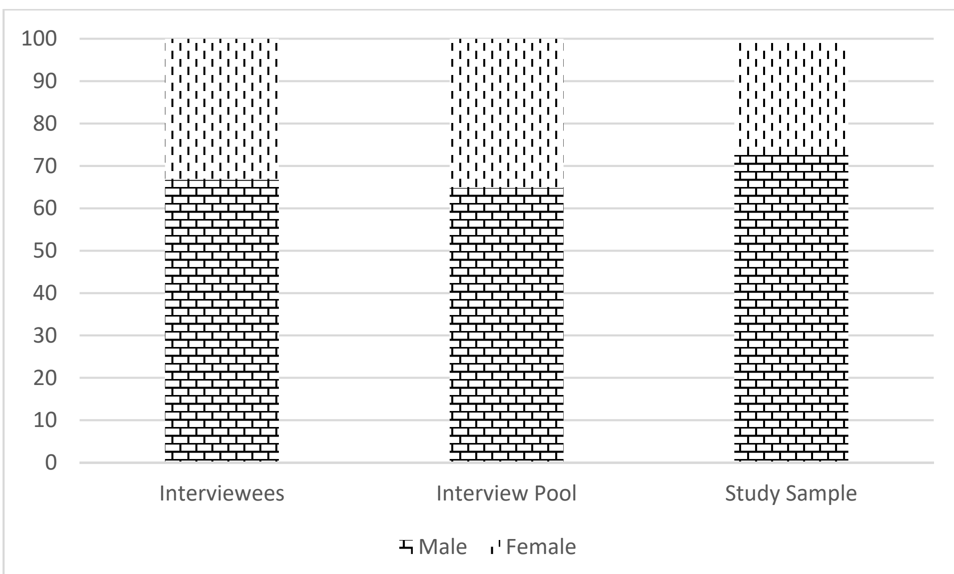

Figure 3.2: Percentages of Male and Female Students, Spring 2021

The most notable feature of these distributions is that the percentage of female participants in the **Interview Pool** is larger than its counterpart in either **Study Sample.** This was due to the fact that a larger number of women volunteered for interviews than the predicted percentage in the **Study Sample, Fall 2020**. A representative sample of **Interviewees** contained a 2:1 ratio of male to female students, because only the members of the **Interview Pool** were available for interviews. Therefore, I chose half as many female as male participants as **Prospective Interviewees**, and, fortunately, was able to maintain this ratio among the **Interviewees**.

The second stratification factor for selecting the **Prospective Interviewees** was a predicted learning approach based on responses to a survey question, “What is your purpose for studying in ENGE 1215?” The survey instrument allowed students to select any or all of the following five alternative responses:

1. Need to pass the course (indicates a surface or surface-achieving approach)
2. Want to get an A in the course (indicates a surface-achieving or deep-achieving approach)
3. Need to “do well” in the course to succeed in future courses (indicates a deep-achieving approach)
4. Interested in the course material (indicates a deep approach)
5. Like to learn new things by studying them in detail (indicates a deep approach)

The Prospective Interviewees were then sampled randomly, while maintaining both the 2:1 gender ratio and a proportional distribution of anticipated learning approaches in Table 3.4 on the next page.

Table 3.4: Choices for the Purpose of Studying in ENGE 1215, Fall 2020
Note: **Bold** indicates the largest number of responses within each group

Response	Interviewees	Interview Pool	Study Sample
Pass	**3**	7	32
Get an A	1	14	**53**
Future Success	0	6	27
Interest	1	2	11
Learn New Things	0	0	2
Pass AND get an A	**3**	**17**	49
Pass AND Future Success	1	12	41
Pass AND Interest	1	1	10
Pass AND Learn New Things	0	0	1
Get an A AND Future Success	1	11	42
Get an A AND Interest	**3**	8	35
Get an A AND Learn New Things	1	3	7
Future Success AND Interest	0	5	16
Future Success AND Learn New Things	0	0	1
Interest AND Learn New Things	0	2	9

3.4 Data Collection Methods and Protocols

Data collection methods included the addition of Likert-type learning approach- and learning strategy-related questions to the ENGE 1215 and ENGE 1216 End of Semester Surveys, which were administered during the Fall 2020 and Spring 2021 semesters, respectively. Quantitative methods were applied to the survey data for both **Study Samples**, which included the **Interviewees**, with the intent to further identify similarities and differences in learning approaches and strategies in ENGE courses and courses in science, mathematics, and non-technical areas of study.

After the ENGE 1215 End of Semester Survey data were collected, fifteen interviews were conducted with selected members of the **Interview Pool** (see Table 3.2). The interviews were recorded, transcribed, and coded to yield qualitative results. The selection of interviewees was informed by a portion of the survey results, and the remaining survey results were triangulated with the results from interview transcript coding. The common thread linking the results from each type of inquiry lies with the **Interviewees'** data, since the **Interviewees**, with one exception, were also members of both **Study Samples**.

3.4.1 Quantitative Methods and Protocols

This section contains a description of the study constructs and how they were measured, a short history of survey development, and details about the administration of the survey. The survey questions were added to an established survey that was administered to all students in ENGE 1215 at the end of the Fall 2020 semester.

3.4.1.1 What the Survey Measured

The overall purpose of a survey or questionnaire is to provide data for informed decision making, where the decision is informed by both the similarity of responses and the ways in which they differ (Krathwohl, 2009c). For this study, the ENGE 1215 and ENGE 1216 End of Semester Surveys provided a means of evaluation of the effectiveness of teaching and learning processes, as perceived by students (Kember & Ginns, 2012).

The quantitative study constructs and their corresponding survey questions are shown in Table 3.5 on the next page.

Table 3.5: Study Constructs and Corresponding Survey Questions

Construct	Survey Question(s)
Purpose for Studying	What is your purpose for studying in ENGE 1215 (Fall) or ENGE 1216 (Spring)?
Previous Advanced Placement (AP) or International Baccalaureate (IB) experience	Did you take Advanced Placement or International Baccalaureate courses in high school?
Gender	What is your gender (check all that apply)?
Kember Reflection Model: Habitual Action stage	• As long as I can remember handout material for exams or assignments, I do not have to think too much. • If I follow what the lecturer says, I do not have to think too much in this course.
Kember Reflection Model: Understanding stage	• This course requires me to understand concepts taught by the lecturer. • In this course, I have to continually think about the material that I am being taught.
Kember Reflection Model: Reflection stage	• I sometimes question the way others do something and try to think of a better way. • I often re-appraise my experience so I can learn from it and improve for my next performance.
Kember Reflection Model: Critical Reflection stage	• This course has challenged some of my firmly held ideas. • As a result of this course, I have changed my normal way of studying.

3.4.1.2 How the Survey Was Developed

My survey questions were added to the existing ENGE 1215 and ENGE 1216 End of Semester Surveys. I was then able to collect data from the largest possible study samples during each of two semesters, albeit with constraints imposed by voluntary consent for availability of both study data and interviewing. Therefore, to overcome these two constraints, the first three survey questions were developed in order to assure **Interviewee** representation of the **Study Samples** to the extent possible. The eight questions relating to the Kember reflection model stages were adapted from Kember's original 16-question Reflection Questionnaire (Kember et al., 2000; Leung & Kember, 2003). Kember's work in reflective thinking and learning was derived from the work of Mezirow (1991), and the Kember questionnaire was validated by Kember, et al. (2000), Phan (2008, 2009) and Kalk, Luik, Taimalu & Täht (2014).

Each of the eight questions was related to one of the four stages of the Kember model, as shown in Table 3.5. The questions were repeated four times to allow participants to answer them separately for their engineering, science, mathematics, and non-technical courses. Participants were asked to respond to each question using the following Likert-type scale:

- Strongly Agree
- Generally Agree
- Neither Agree nor Disagree
- Generally Disagree
- Strongly Disagree

3.4.1.3 How and When the Surveys Were Administered

The data were collected as part of the ENGE 1215 End of Semester Survey in December 2020, and the ENGE 1216 End of Semester Survey in May 2021. Both surveys contained all of the study questions listed in Table 3.5 and provided a practical way to collect data about the characteristics of a large group of participants. The survey instruments had been used for multiple semesters, were administered online through the Qualtrics® platform, and readily incorporated the questions that I used to collect the data.

Data were made available from the **Interviewees**, **Study Sample, Fall 2020**, and **Study Sample, Spring 2021** groups. The number of participants in each group and the relationships among the groups are shown in Tables 3.2 and 3.3.

3.4.2 Qualitative Methods and Protocols

This section contains the qualitative study constructs and their corresponding interview questions, the background for the interview protocol, and details about how and when the interviews were conducted. The interview questions were informed by previous studies about learning strategies, which employed surveys rather than interviews or focus groups (Hartwig & Dunlosky, 2012; Kornell & Son, 2009; Morehead et al., 2016).

3.4.2.1 Study Constructs and Corresponding Interview Questions

The qualitative study constructs and their corresponding interview questions are shown in Table 3.6.

Table 3.6: Qualitative Constructs and Corresponding Interview Questions

Construct	Interview Question(s)
Products or goals of studying as indicators of learning approach; i.e., "What do I want to accomplish?"	• What is your overall purpose for studying? • How can you tell when you understand something?
Processes of studying, or learning strategies; i.e., "How do I get there?"	• How do you decide what to study next? • What are your most useful methods for learning course material? • How do you handle difficult material? • What kinds of questions do you ask yourself while you are studying? • How do you regard study groups; i.e., groups of students who get together to study?

3.4.2.2 How the Interview Protocol Was Developed

I chose a phenomenographic approach to conduct semi-structured interviews because it offered the most promising way to acquire authentic responses from the participants about learning approaches and strategies. The fact that one of Biggs' predecessors in approaches to learning (namely, Marton) used phenomenography to study variations in learning among college students provided evidence for the suitability of this protocol (Marton, 1992; Marton & Pong, 2005; Marton & Saljo, 1976). Further guidance for phenomenological interviews was provided by Bevan (2014) and by Hoffding and Martiny (2015).

The importance of the **Interviewees'** contexts set the stage to reveal their choices of learning strategies (Bevan, 2014). Descriptive questions were important for providing rich descriptions of context, including the **Interviewee's** underlying goals, motives, habits, and regard for knowledge. Not all of these components of context were articulated by the **Interviewees** but could have been elicited by the interviewer, as both participated in the construction of knowledge (Hoffding & Martiny, 2015). This was the "structured" part of the interview, in which I, as the interviewer guided each **Interviewee** toward revealing useful information.

Follow-on questions were important to prompt the **Interviewee** to provide additional detail to the context (Bevan, 2014). Follow-on questions also revealed "pre-reflective" insights, meaning ideas or thoughts that were not evident to the **Interviewee** before the interview but that were prompted by one or more follow-on questions leading to reflection-in-action (Hoffding & Martiny, 2015; Schön, 1983). This was another example of participation in the generation of knowledge by the interviewer as an application of the constructivist worldview (Baxter-Magolda, 2004). Follow-on questions, such as this one, provided an opportunity to recall critical incidents: "Can you tell me about a situation when you had two tests to study for, and both were important? Which one received more of your attention?" (Bevan, 2014; Flanagan, 1954). The recounting of critical incidents was useful because it revealed incidents or events that were important to the

Interviewee or otherwise provided a rich illustration of the importance of context (Flanagan, 1954).

The interview questions were tested in an online pilot interview with a former student. This interview was recorded, transcribed, and member-checked for accuracy. After member-checking, the questions were modified and potential follow-on questions were developed for use in the interviews with the **Interviewees**.

3.4.2.3 How and When the Interviews Were Conducted

The first twenty-four **Prospective Interviewees** were invited to participate in a 30-minute online interview using Zoom®. Twelve **Prospective Interviewees** accepted the invitation. The **Prospective Interviewees** in a second group of 24 were then invited to participate in a 30-minute online interview using Zoom®. Three **Prospective Interviewees** accepted the invitation, for a total of 10 male and 5 female **Interviewees**.

The interview questions listed in Table 3.5 were sent to each **Interviewee** prior to their interview. A total of fifteen interviews, each 15–30 minutes in duration, were conducted over Zoom from March 2 to March 26, 2021. Interviews were recorded, transcribed, and de-identified. Transcripts were checked for accuracy with the interview recordings, and minor corrections were made where necessary. Transcripts were then sent to the **Interviewees** for member checking. Two transcripts were returned with additions and corrections, and the remaining thirteen were confirmed to be accurate as transcribed.

The **Interviewees** were each given a gift card as compensation for their time, as well as the opportunity to enter a drawing for an Eno® hammock. The hammock drawing was held after the interview transcripts had been member-checked.

3.5 Data Analysis Procedures

Both quantitative and qualitative methods are described in this section. Both types of analysis were used in order to produce more comprehensive results than those from either type on its own. The quantitative methods involved appropriate yet less obvious statistical parameters, while the qualitative methods included *a priori*, pattern, and comparative coding.

3.5.1 Quantitative Analysis Procedure

Because the **Interviewees** were part of both **Study Sample** groups, and had completed the End of Semester Surveys at the same times as each **Study Sample** group, their reflection-related survey results were compared to those of either **Study Sample** group to investigate similarities and differences. Medians, first quartiles, third quartiles, and interquartile range values were calculated, tabulated, and plotted for the reflection-related survey results by **Interviewees Fall 2020**, **Study Sample Fall 2020**, **Interviewees Spring 2021,** and **Study Sample Spring 2021.**

The use of medians, rather than means, is considered to be more appropriate when dealing with ordinal data such as levels of agreement in a Likert scale (Kostoulas, 2013). The reason for this is because "the psychological distance" between any two levels of agreement in a Likert scale is not uniformly equal throughout the scale, and it would have to be for a mean or average value to be valid (Kostoulas, 2013).

Because the use of a mean or average value for a set of Likert scores was not appropriate, neither was the use of a standard deviation. For medians, the distribution of the data was described by quartiles and the interquartile range (IQR) instead (Krathwohl, 2009b). While the median represents the "middle value" of the data, the entire distribution can be divided into quartiles, where the first quartile is the value at which 25% of the data lie to the left in the distribution, the second quartile is the median, and the third quartile is the value at which 25% of the data lie to the right in the distribution (Krathwohl, 2009b). This means that 50% of the data lay between the first and third quartiles, or the interquartile range (Krathwohl, 2009b). A low IQR value, relative to the magnitude of the data, indicates that the median was a better representation of the data than a median with a high IQR (Glen, 2021; Krathwohl, 2009b).

Separate sets of reflection-related survey results were calculated and tabulated for each of the four types of courses taken during each semester. Each median value was associated with a Likert agreement level, where decimal values were assigned to the combinations of levels as follows:

- Strongly Agree: 5
- Strongly Agree/Generally Agree: 4.5
- Generally Agree: 4
- Neither Agree nor Disagree/Generally Agree: 3.5
- Neither Agree nor Disagree: 3
- Generally Disagree/Neither Agree nor Disagree: 2.5
- Generally Disagree: 2
- Generally Disagree/Strongly Disagree: 1.5
- Strongly Disagree: 1

3.5.2 Qualitative Analysis Procedure

The interview transcripts were summarized by key phrases and sentences, and were then coded to identify specific learning approaches and strategies as well as their contexts. Responses were highlighted for key phrases and sentences that expressed their essence. These were later identified as “Examples from the Data” in the reporting of results.

The sequence of coding methods is shown in Figure 3.5.

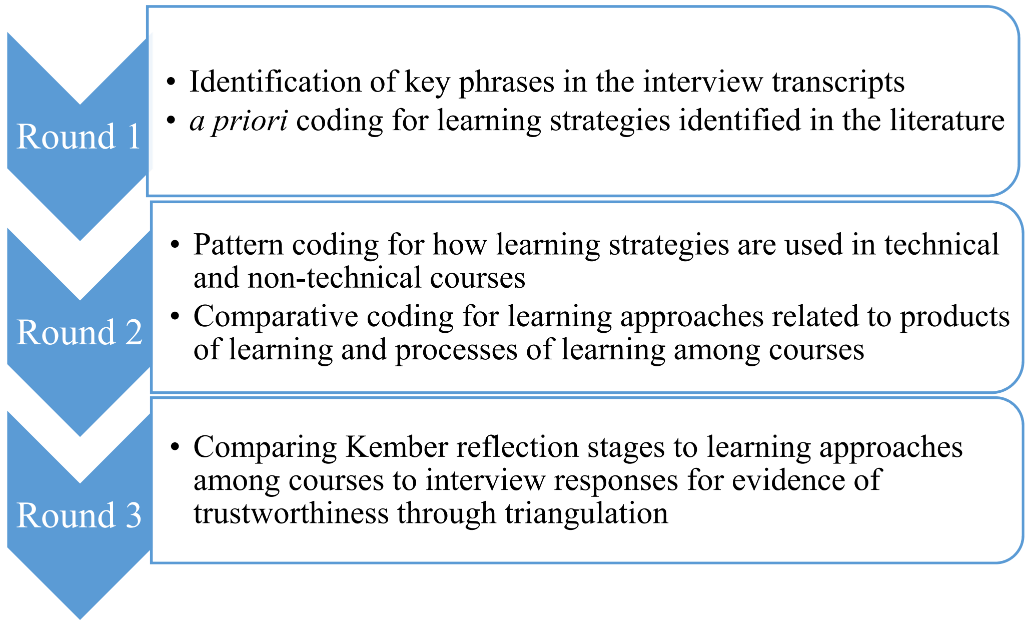

Figure 3.5: Analytical Methods for Interview Data, in Sequence

The first round of analysis for the interview transcripts was based on *a priori* codes identified in the literature, then specific learning strategies, themes and/or patterns identified in the literature (Saldaña, 2016). The *a priori* codes are listed in Table 3.7 and 3.8 on the next six pages. As key phrases and sentences were identified and compared to the list of *a priori* codes, it became apparent that each *a priori* code could be applied according to one or more of the four learning approaches in the Biggs framework: surface, surface-achieving, deep-achieving, or deep. Therefore, it became necessary to differentiate each *a priori* code according to how a student might exhibit it under a particular learning approach. These differentiations appear in Table 3.8.

Table 3.7: Questions for Semi-Structured Interviews and Corresponding *a priori* Codes and Sources

Question	*a priori* Codes and Sources
What is your purpose for studying?	**Forming value judgments about what is learned** (Floyd et al., 2009; Naude et al., 2014; Wigfield & Eccles, 2000)
	Memorization (Biggs, 1988; Felder & Brent, 2005)
	Monitoring and evaluating the use of strategies (Crede & Kuncel, 2008)
	Planning and goal setting (Biggs, 1979, 1988, 1999; Crede & Kuncel, 2008; Floyd et al., 2009; Hartwig & Dunlosky, 2012; Morehead et al., 2016)
	Self-directing and self-regulating one's learning using metacognition; e.g., self-teaching, self-questioning, self- monitoring, and self-evaluation (Ambrose, S.A. et al., 2010; Crede & Kuncel, 2008; Karpicke, 2009)
	Working practice problems and practice tests (Bhaduri & Matusovich, 2017; Dirkx et. al., 2019; Felder & Brent, 2005; Hartwig & Dunlosky, 2012; Karpicke, 2009)
How can you tell when you understand something?	**Checking results** (Crede & Kuncel, 2008)
	Discover and explore patterns in knowledge through reflection (Hatton & Smith, 1995; Kember et al., 2008; King & Kitchener, 1994; Moon, 2007)
	Finding real-world examples of course material using reflection (Chabon & Lee-Wilkerson, 2006; Kember, et al., 2008; King & Kitchener, 1994; Moon, 2007)
	Forming value judgments about what is learned (Floyd et al., 2009; Naude et al., 2014; Wigfield & Eccles, 2000)
	Memorization (Biggs, 1988; Felder & Brent, 2005)
	Self-directing and self-regulating one's learning using metacognition; e.g., self-teaching, self-questioning, self- monitoring, and self-evaluation (Ambrose, S.A. et al., 2010; Crede & Kuncel, 2008; Karpicke, 2009)
	Teaching others to offer help and reinforce own understanding (Hofer & Yu, 2003)
	Working practice problems and practice tests (Bhaduri & Matusovich, 2017; Dirkx et. al., 2019; Felder & Brent, 2005; Hartwig & Dunlosky, 2012; Karpicke, 2009)
How do you decide what to study next?	**Compare new knowledge to prior knowledge using reflection** (Chabon & Lee-Wilkerson, 2006; Hatton & Smith, 1995; Kember, et al.,2008; King & Kitchener, 1994; Moon, 2007)
	Employing interleaved practice; i.e., come back to it later (Dirkx et al., 2019)
	Forming value judgments about what is learned (Floyd et al., 2009; Naude et al., 2014; Wigfield & Eccles, 2000)
	Planning and goal setting (Biggs, 1979, 1988, 1999; Crede & Kuncel, 2008; Floyd et al., 2009; Hartwig & Dunlosky, 2012; Morehead et al., 2016)
What are your most useful methods of learning course material?	**Compare new knowledge to prior knowledge using reflection** (Chabon & Lee-Wilkerson, 2006; Hatton & Smith, 1995; Kember, et al., 2008; King & Kitchener, 1994; Moon, 2007)

	Discovering and exploring patterns in knowledge through reflection (Hatton & Smith, 1995; Kember et al., 2008; King & Kitchener, 1994; Moon, 2007)
	Employing interleaved practice, i.e., come back to it later (Dirkx et al., 2019)
	Forming value judgments about what is learned (Floyd et al., 2009; Naude et al., 2014; Wigfield & Eccles, 2000)
	Memorization (Biggs, 1988; Felder & Brent, 2005)
	Monitoring and evaluating the use of strategies (Crede & Kuncel, 2008)
	Note taking from lectures and/or textbook (Crede & Kuncel, 2008; Karpicke, 2009)
	Planning and goal setting (Biggs, 1979, 1988, 1999; Crede & Kuncel, 2008; Floyd et al., 2009; Hartwig & Dunlosky, 2012; Morehead et al., 2016)
	Seeking help from textbooks and online sources (Dirkx et al., 2019)
	Seeking help with understanding and problem solving from one or more individuals (Birenbaum, 1997; Hartwig & Dunlosky, 2012; Stigmar, 2016)
	Self-directing and self-regulating one's learning using metacognition; e.g., self-teaching, self-questioning, self- monitoring, and self-evaluation (Ambrose, S.A. et al., 2010; Crede & Kuncel, 2008; Karpicke, 2009)
	Working practice problems and practice tests (Bhaduri & Matusovich, 2017; Dirkx et. al., 2019; Felder & Brent, 2005; Hartwig & Dunlosky, 2012; Karpicke, 2009)
How do you handle difficult material?	**Comparing new knowledge to prior knowledge using reflection** (Chabon & Lee-Wilkerson, 2006; Hatton & Smith, 1995; Kember, et al., 2008; King & Kitchener, 1994; Moon, 2007)
	Discover and explore patterns in knowledge through reflection (Hatton & Smith, 1995; Kember et al., 2008; King & Kitchener, 1994; Moon, 2007)
	Employing interleaved practice; i.e., come back to it later (Dirkx et al., 2019)
	Planning and goal setting (Biggs, 1979, 1988, 1999; Crede & Kuncel, 2008; Floyd et al., 2009; Hartwig & Dunlosky, 2012; Morehead et al., 2016)
	Seeking help from textbooks and online sources (Dirkx et al., 2019)
	Seeking help with understanding and problem solving from one or more individuals (Birenbaum, 1997; Hartwig & Dunlosky, 2012; Stigmar, 2016)
	Self-directing and self-regulating one's learning using metacognition; e.g., self-teaching, self-questioning, self- monitoring, and self-evaluation (Ambrose, S.A. et al., 2010; Crede & Kuncel, 2008; Karpicke, 2009)
	Working practice problems and practice tests (Bhaduri & Matusovich, 2017; Dirkx et. al., 2019; Felder & Brent, 2005; Hartwig & Dunlosky, 2012; Karpicke, 2009)
What kinds of questions do you ask yourself while you are studying?	**Checking results** (Crede & Kuncel, 2008)
	Comparing new knowledge to prior knowledge using reflection (Chabon & Lee-Wilkerson, 2006; Hatton & Smith, 1995; Kember, et al., 2008; King & Kitchener, 1994; Moon, 2007)
	Discovering and exploring patterns in knowledge through reflection (Hatton & Smith, 1995; Kember et al., 2008; King & Kitchener, 1994; Moon, 2007)

	Finding real-world examples of course material using reflection (Chabon & Lee-Wilkerson, 2006; Kember, et al., 2008; King & Kitchener, 1994; Moon, 2007)
	Forming value judgments about what is learned (Floyd et al., 2009; Naude et al., 2014; Wigfield & Eccles, 2000)
	Memorization (Biggs, 1988; Felder & Brent, 2005)
	Planning and goal setting (Biggs, 1979, 1988, 1999; Crede & Kuncel, 2008; Floyd et al., 2009; Hartwig & Dunlosky, 2012; Morehead et al., 2016)
	Self-directing and self-regulating one's learning using metacognition, e.g., self-teaching, self-questioning, self- monitoring, and self-evaluation (Ambrose, S.A. et al., 2010; Crede & Kuncel, 2008; Karpicke, 2009)
	Teaching others to offer help and reinforce own understanding (Hofer & Yu, 2003)
How do you regard study groups, i.e, students who get together to study?	**Checking results** (Crede & Kuncel, 2008)
	Employing interleaved practice, i.e., come back to it later (Dirkx et al., 2019)
	Forming value judgments about what is learned (Floyd et al., 2009; Naude et al., 2014; Wigfield & Eccles, 2000)
	Monitoring and evaluating the use of strategies (Crede & Kuncel, 2008)
	Planning and goal setting (Biggs, 1979, 1988, 1999; Crede & Kuncel, 2008; Floyd et al., 2009; Hartwig & Dunlosky, 2012; Morehead et al., 2016)
	Seeking help with understanding and problem solving from one or more individuals (Birenbaum, 1997; Hartwig & Dunlosky, 2012; Stigmar, 2016)
	Self-directing and self-regulating one's learning using metacognition, e.g., self-teaching, self-questioning, self- monitoring, and self-evaluation (Ambrose, S.A. et al., 2010; Crede & Kuncel, 2008; Karpicke, 2009)
	Teaching others to offer help and reinforce own understanding (Hofer & Yu, 2003)

Table 3.8: ***a priori*** **Codes for Surface, Deep, and Achieving Learning Approaches Associated with Specific Learning Strategies**

Learning Strategy a priori Code	**Surface Approach**	**Surface-Achieving Approach**	**Deep-Achieving Approach**	**Deep Approach**
Checking results (Crede & Kuncel, 2008)	Does not check results for possible errors	Checks practice problem and test results if time permits	Checks practice problem and test results for errors in computation to improve test performance	Checks results habitually by asking, for example, "Does this result make sense?"
Comparing new knowledge to prior knowledge using reflection (Chabon & Lee-Wilkerson, 2006; Hatton & Smith, 1995; Kember, et al., 2008; King & Kitchener, 1994; Moon, 2007)	Studies all course topics without comparison to prior knowledge for reinforcement, often with rote memorization or adherence to procedures.	Studies course topics for testing with occasional comparison to prior knowledge to reinforce a limited understanding of course concepts.	Recalls prior knowledge while studying in order to reinforce conceptual understanding for various test questions or problems.	Integrates new knowledge with prior knowledge gained from multiple courses to strengthen conceptual understanding for retention and transfer.
Discovering and exploring patterns in knowledge through reflection (Hatton & Smith, 1995; Kember et al., 2008; King & Kitchener, 1994; Moon, 2007)	Studies all course topics in isolation, with little relationship to one another.	Recognizes how course topics may be related for testing purposes.	Identifies patterns and relationships among topics within a course, in order to reinforce conceptual knowledge for testing.	Identifies patterns and relationships among topics in two or more courses to reinforce conceptual knowledge.
Employing interleaved practice, i.e., come back to it later (Dirkx et al., 2019)	Works just before an assignment or test is due, leaving no opportunity to "come back to it later."	Studies for tests according to deadlines; i.e., only studies for one test at a time, with breaks from study as time permits.	Studies far enough in advance to allow for breaks, with subsequent return to the test-related topics.	Divides study material and available time into increments and studies each material increment within its time increment, taking breaks between topics to refresh and maintain focus.
Finding real-world examples of course material using reflection (Chabon & Lee-Wilkerson, 2006; Kember, et al., 2008; King & Kitchener, 1994; Moon, 2007)	Studies course topics in isolation, with no comparison to real-world examples.	Studies with an attempt at understanding real-world examples given with the course material, expecting to see the same examples in test questions or problems.	Develops a personal meaning to course material through additional real-world examples and how they illustrate course concepts.	Develops a personal meaning to course material through additional real-world examples and how they illustrate course concepts; discovers and corrects misconceptions in conceptual knowledge.

Forming value judgments about what is learned (Floyd et al., 2009; Naude et al., 2014; Wigfield & Eccles, 2000)	Relative course value is driven by deadlines.	First, study for the test, next, assign a higher value to courses with currently poor performance.	Course value is determined by difficulty in mastering material for tests.	Course value is determined by its contribution to career goals, and/or by personal interest in the subject matter.
Memorization (Biggs, 1988; Felder & Brent, 2005)	Memorizes a definition, term or formula without regard for meaning	Memorizes a definition, term, or formula in order to repeat it on a test.	Memorizes relationships among definitions, terms or formulas in order to answer test questions quickly and accurately.	Explores the meaning of term, variables, and formulas as a key to memorization and understanding
Monitoring and evaluating the use of strategies (Crede & Kuncel, 2008)	Does not evaluate the usefulness of any particular learning strategy while studying.	Limits the use of strategies to acquiring an estimate of necessary test-related knowledge.	Monitors own understanding and selects strategies which might enable high test performance.	Monitors own understanding frequently and selects strategies to build mastery of course material.
Note taking from lectures and/or textbook (Crede & Kuncel, 2008; Karpicke, 2009)	Takes notes randomly during class or while reading the course textbook.	Tries to memorize notes to prepare for a test.	Re-writes and may augment notes to prepare for a test	Develops a well-organized study guide from own well-detailed course notes.
Planning and goal setting (Biggs, 1979, 1988, 1999; Crede & Kuncel, 2008; Floyd et al., 2009; Hartwig & Dunlosky, 2012; Morehead et al., 2016)	Does not set goals or plans for study.	Sets goals, allocates resources, and forms study plans based exclusively on deadlines for assignments and tests.	Sets goals, allocates resources, and forms study plans according to recent and future homework and test performance.	Sets goals, allocates resources, and forms study plans according to career aspirations and engagement with learning.
Seeking help from textbooks and online sources (Dirkx et al., 2019)	Seeks a few sources of similar problems as those in homework or practice tests to find out what formula to use or definition to memorize.	Seeks similar problems as those in homework and practice tests and reads the explanations for how to solve them.	Seeks alternative sources of online tutorials for difficult material to address gaps in understanding for better test performance.	Explores alternative online sources to deepen understanding of what an item of knowledge is as well as how to use it.
Seeking help with understanding and problem solving from one or more individuals (Birenbaum, 1997; Hartwig & Dunlosky, 2012; Stigmar, 2016)	Seeks help with the intent to just determine the correct answers without attempting to understand why the answers are correct.	Seeks help with understanding just enough to perform adequately on a test, and only trusts the instructor to tell them what is correct.	Seeks help with understanding from peers and then from instructors, as necessary, with a focus on high test performance.	Seeks help to deepen understanding of course material, explore alternative ways of understanding, and integrate concepts between or among courses.
Self-directing and self-regulating one's learning	Does not engage in self-teaching or self-	Avoids self-teaching and self-questioning; often	Self-teaches and self-questions about course	Engages in self-teaching and self-questioning readily in

using metacognition, e.g., self-teaching, self-questioning, self-monitoring, and self-evaluation (Ambrose, S.A. et al., 2010; Crede & Kuncel, 2008; Karpicke, 2009)	questioning, nor monitor or evaluate their understanding of course material.	monitors study behavior superficially and evaluates understanding unrealistically.	material to resolve difficulties; monitors and evaluates understanding in preparation for a test or while doing homework.	order to acquire additional knowledge; monitors and evaluates understanding for retention and transfer to concurrent and future courses.
Teaching others to offer help and reinforce own understanding (Hofer & Yu, 2003)	Cannot teach others because own conceptual understanding is weak.	Teaches others what they know for an upcoming test.	Teaches others such that they can easily understand difficult concepts for homework assignments and tests.	Teaches others about concepts and their interrelationships with or outside a given course.
Working practice problems and practice tests (Bhaduri & Matusovich, 2017; Dirkx et. al., 2019; Felder & Brent, 2005; Hartwig & Dunlosky, 2012; Karpicke, 2009)	Works on only assigned homework problems.	Works on additional practice problems and practice tests supplied with the course.	Seeks additional practice problems in textbooks and online, but only those for which the correct answers are available.	Seeks additional practice problems in textbooks and outside the course; may develop own practice problems and apply concepts to a variety of problem types.

The *a priori* codes are listed alphabetically in Table 3.8. Reflective learning strategies were included among the *a priori* codes, and were also delineated according to underlying learning approaches. The results of the first round addressed my first research sub-question about how the interviewees customized their learning strategies approaches and strategies both within and among their courses. By linking the *a priori* codes to key phrases in the interview transcripts, the phenomenon of learning approaches and strategies can be more clearly identified and as what the **Interviewees** do and how they do it (Akerlind, 2005).

The second round of analysis and coding employed pattern coding as a way to organize the first round codes into categories, as well as detect differences in the choices of learning approaches and strategies among courses (Bruce, 1994; Hoffding & Martiny, 2015; Saldana, 2016). This round provided further evidence to address my first research sub-question about variations in the use of learning strategies among courses, especially the similarities and differences between technical and non-technical courses.

The similarities and differences among categories illustrate the influence of course context between technical and non-technical courses. In addition, it was important to value all responses for both types of courses equally (Bruce, 1994).

When an **Interviewee** did not indicate where they would use a particular learning strategy, either by course name or description, I assumed that this strategy was applicable to both technical and non-technical courses. I made this assumption on the basis that the strategy was stated generically, because the Interviewee did not specify whether they used it in a technical or a non-technical course.

Comparative coding was also used in the second round to further categorize interview responses according to Biggs' metalearning questions (1988):

- What do I want to get out of this? (i.e., the product of study)
- How do I get there? (i.e., the process of studying)

This type of coding revealed what combinations of product- and process-oriented strategies were described by each **Interviewee**, which provided additional answers to my first research sub-question and additional categories of this phenomenon (Akerlind, 2005; Hoffding & Martiny, 2015). These results also indicated students' motives for studying and how their motives influenced their choices of learning approaches and strategies (Biggs, 1988). For example, learners with the surface-achieving or deep-achieving approaches tended to express their strategies in terms of what they believed to be necessary to obtain high grades (Biggs, 1988). However, given the expected customization of learning approaches and strategies among courses, which led to my first research sub-question, an **Interviewee** indicated that they used a combination of learning approaches to attain a goal, particularly if it was difficult to attain or otherwise complex.

The third round of analysis addressed my second research sub-question about the use of reflective learning strategies. This round also involved the triangulation of the reflection-related survey responses with those expressed by individual **Interviewees** who exhibited the *a priori* codes associated with reflection (see Tables 3.7 and 3.8). In this case, the reflection-related survey results were expected to either corroborate or refute the results obtained from the interviews. While some of the **Interviewees** described certain learning strategies as reflection, they also described reflective strategies using other terms, such as detecting patterns or relationships among items of knowledge or comparing new knowledge to prior knowledge. These strategies are also reflective, even though they do not contain the term "reflection."

Results for the identification of reflective learning strategies and related learning approaches among the **Interviewees** and the **Study Samples** were expected to demonstrate the following:

- A general trend toward "surface" vs. "deep" learning among students in ENGE 1215 or 1216, on the basis that Leung and Kember (2003) linked the first stage in their reflection model to the "surface" learning approach, and the remaining three stages to the "deep" learning approach;
- How reflection was promoted by certain types of courses for some students and not others;
- If there was a certain type of course that encouraged reflection by a large number of students.

3.5.3 Justification to Combine Quantitative and Qualitative Methods

Because of the diversity of the first-year student population at our institution, it is reasonable to expect that these students would exhibit a variety of learning approaches and strategies, have differing educational backgrounds, and have differing expectations about their higher education experience. Therefore, a research design with only quantitative methods, such as surveys, may not provide sufficient information to address. I used both quantitative and qualitative methods to collect and analyze the study data in order to provide more comprehensive answers to my research question and sub-questions. As a result, I found that my combination of methods yielded data and the opportunity to improve construct validity through triangulation, complementarity, and expansion particularly among the Interviewees' interview and survey data (Creswell & Plano Clark, 2011; Greene, Caracelli & Graham, 1989).

As I read about previous studies, I found their results to be informative but incomplete, due to the limitations of the instruments that were used and the non-specification of participants' academic status. Knowing from my own experience as a first-year educator and former engineering student that academic requirements are more demanding in the second year than earlier and that first-year students were often ill-prepared to meet them, due, in part, to the reasons described in Chapter 1, it was necessary to provide first-year educators and their students with a highly detailed description of the current state of the learning approaches and strategies in use by this study population as a starting point for further engagement with learning.

The End of Semester Survey quantitative data also provided a defensible basis for the selection of **Interviewees**. After the interviews were conducted and analyzed, the results were triangulated with the **Interviewees'** survey data to increase the reliability and trustworthiness of the interview protocol. In addition, it was not feasible to interview a large enough number of **Interviewees** in order to accurately determine the **Study Sample** results.

3.6 Validity and Trustworthiness Approaches

3.6.1 Quality Through Alignment

The overall quality of this study was demonstrated through alignment among the research question, conceptual framework, research methods, results, and conclusions (AERA, 2006). In my study, by using the constructs of learning approaches and strategies, I applied Biggs' recommendations for constructive alignment between anticipated outcomes and the means by which to achieve them (Biggs, 1996).

The theoretical framework provided a justification for exploring the research question focusing on students' learning strategies, as it originated with Biggs' distinctions among "surface," "deep," and "achieving" learning approaches and their associated strategies (Biggs, 1988, 1996, 1999). The data collection protocols, i.e., End of Semester Surveys and interviews, yielded data about existing learning strategies and tendencies toward the surface, surface-achieving, deep-achieving, or deep approach to learning, while allowing for the possibility that the participants might have used a combination of approaches within and among their courses.

The data collection method described earlier contained an End of Semester Survey, to which eight reflection-related questions were added, and which was administered at the end of the Fall 2020 and Spring 2021 semesters. The results from the Fall 2021 End of Semester Survey were used to select the **Interviewees** from the **Study Sample Fall 2020**. The **Interviewees** were then asked to describe their learning strategies in semi-structured interviews. These methods addressed both of my research sub-questions by providing qualitative and quantitative data about learning approaches and strategies and detailed data about the use of reflective learning strategies.

Interviewees' results from the reflection-related survey questions were expected to corroborate or refute the results obtained through the interviews, through the relationships of Biggs' "surface" approach to Kember's "Habitual Action" stage of reflection and Biggs' "deep" approach" to Kember's remaining three reflection stages: Understanding, Reflection, and Critical Reflection (Kember et. al., 2000, Kember et. al., 2008; Leung & Kember, 2003). By comparing the **Interviewees'** reflection-related survey questions and interview results, alignment among my research questions, conceptual frameworks, data collection methods, and data analysis methods was further demonstrated (Denzin & Lincoln, 1998; Patton, 1990). The triangulation of data also minimized any error that might have been associated with using only one data collection or analysis method (Patton, 1990).

Qualitative studies may be evaluated for validity and reliability, although Creswell labels all quality-related methods as "validation." (Creswell & Poth, 2018). I demonstrated validation using these methods from Creswell and others:

- Coding of the interview responses by at least one alternate rater, using the same coding methods, followed by reconciliation of any major differences (Creswell & Poth, 2018c; Hsieh & Shannon, 2005; Moskal, Leydens & Pavelich, 2002);
- Disclosure of researcher bias to demonstrate reflexivity (Borrego et al., 2009; Creswell & Poth, 2018b; Guba & Lincoln, 1994; Leydens, Moskal & Pavelich, 2004; Malterud, 2001), and
- Peer reviews of the study and its results to demonstrate effective communication for understanding and acceptance (Creswell & Poth, 2018).

The End of Semester Survey data were subject to validation through both content and construct validity (Creswell & Plano Clark, 2011; Leydens, J.A. et al., 2004). This survey had been administered multiple times, meaning that the questions had been modified over the years to allow for a sufficient number and variety of potential responses based on existing results. While an external standard for validity has not been applied to the End of Semester Surveys, construct validity was similarly proven, repeatedly, by compiling and evaluating the survey results over several years of administration for similarities and differences. Regarding the reflection-related survey questions and the fact that they were added to the End of Semester Surveys beginning in Fall 2020, and connected to my exploration of the effect of reflection on learning approaches and strategies, part of their construct validity lies in the fact that Biggs and Kember had established a defensible relationship between learning approaches and stages of reflection (Biggs et al., 2001). This relationship was further reinforced by later studies that were reported in the literature (Baeten, Kyndt, Struyven & Dochy, 2010; Biggs & Tang, 2011; Kember & Ginns, 2012).

In addition, the Kember group and others demonstrated validity of their original sixteen-question reflection survey, from which my reflection-related questions were adapted, through descriptive statistics and factor analysis (Ghanizadeh, 2017; Leung & Kember, 2003; Phan, 2009). While I did not conduct similar analyses on the results of the reflection-related questions in my study, I can compare the Kember questions that I included with the ones that I did not, as shown in Table 3.9 on the next page.

Table 3.9: Original Kember Reflection Questions, with Reflection-Related EOS Survey Questions Listed in Boldface Type (Kember et al., 2000)

Reflection Stage (study construct)	**Kember Survey Questions for Each Stage**
Habitual Action	When I am working on some activities, I can do them without thinking about what I am doing.
Habitual Action	In this course we do things so many times that I start doing them without thinking about it.
Habitual Action	**As long as I can remember handout material for exams or assignments, I do not have to think too much.**
Habitual Action	**If I follow what the lecturer says, I do not have to think too much in this course.**
Understanding	**This course requires me to understand concepts taught by the lecturer.**
Understanding	To pass this course, you need to understand the content.
Understanding	I need to understand the material taught by the teacher in order to perform practical tasks.
Understanding	**In this course, I have to continually think about the material that I am being taught.**
Reflection	**I sometimes question the way others do something and try to think of a better way.**
Reflection	I like to think over what I have been doing and consider alternative ways of doing it.
Reflection	I often reflect on my actions to see whether I could have improved on what I did.
Reflection	**I often re-appraise my experience so I can learn from it and improve for my next performance.**
Critical Reflection	As a result of this course, I have changed the way I look at myself.
Critical Reflection	**This course has challenged some of my firmly held ideas.**
Critical Reflection	**As a result of this course, I have changed my normal way of studying. (originally: way of doing things)**
Critical Reflection	During this course I discovered faults in what I had previously believed to be right.

When I selected the questions shown in boldface in Table 3.9, I considered the context of the first-year technical and non-technical courses and selected eight questions that were best suited to these contexts, to further exercise construct validity (Creswell & Plano Clark, 2011). In addition, it was important to select questions that represented all four constructs equally.

3.6.2 Sources of Bias

In any qualitative inquiry, researchers may spend many hours gathering data through contact with the participant(s), interviewing them, collecting artifacts related to the area of study, and analyzing the data. As a results bias can be introduced by the researchers as they co-construct the data along with the participants during interviews (Borrego et al., 2009; Leydens, J.A. et al., 2004; Malterud, 2001). Researchers also need to be careful about the influence of their own biases as they attempt to exercise empathy with their participants during data collection and analysis. For this study, researcher bias was mitigated through member-checking of the interview transcripts by all of the **Interviewees** and by interrater checking of the coded data.

Another source of research bias that I experienced was the influence of attitudes about surface and deep learning approaches that I observed in the literature, beginning with Biggs and also researchers who implied that a deep learning approach was primarily necessary for strong academic preparation prior to the second year of college (Biggs, 1988, 1996; Downing, 2009; Gore & Hunter, 2010; Kennedy & Upcraft, 2010). However, it is possible that a combination of surface and deep approaches for processing information could be used in concert to strengthen student learning, as described near the end of Section 5.3.1.

Knowing that the *a priori* codes listed in Tables 3.7 and 3.8 could be applied according to any of the four learning approaches, the descriptions in Table 3.8 of how each *a priori* code could be applied were original, and therefore subject to researcher bias. To mitigate this bias, these descriptions were informed by both the literature and the results from the preceding step in the coding process, according to Round 1 in Figure 3.5, Section 3.5.2. Also, the alternative rater used the same table to code the interview data and agreed with the descriptions that I had provided.

A counterpoint to researcher bias lay in the constructivist epistemology, which asserted that meaning resides with the one who perceive it, and that reality is co-constructed through social interaction (Ponterotto, 2005; Vygotsky, 1978). I have found that a constructivist approach to educational research, best described by Baxter-Magolda (2004) and heartily endorsed by Biggs (1988, 1999) may provide the flexibility to allow co-construction of meaning by the participant and the researcher, which can mitigate bias and therefore increase trustworthiness.

While we expected the students to respond truthfully in surveys and interviews, response bias was also possible (Singleton & Straits, 2010). Response bias was mitigated to the extent possible by screening the **Interview Pool** during the selection of **Interviewees** and eliminating those **Prospective Interviewees** who were enrolled in my ENGE 1216 sections during Spring 2021. In addition, the selection of prospective interviewees was limited to **Interview Volunteers** who had previously selected only one or two responses for their purpose for studying in ENGE 1215, in order to further mitigate response bias.

3.6.3 Interrater Reliability

Another method to promote reliability and mitigate my own researcher bias in qualitative research is to invite an independent researcher to code one or more interview transcripts, then compare their results to mine and discuss any differences between these two sets of coded data (Creswell & Plano Clark, 2011; Creswell & Poth, 2018b). This is also necessary to address variations in coding because it is interpretive and therefore somewhat subjective, even though a set of common codes may be used (Creswell & Poth, 2018b).

My interrater was a non-traditional engineering education graduate student with extensive teaching experience in first-year engineering courses, like myself. It was not necessary to train her in how to code, because she had already completed her program's requirement for coursework in qualitative research methods. She was provided with one interview transcript, in which each interview question's responses were listed on their own page. In addition, a set of definitions for the four learning approaches was provided, along with a copy of Table 3.9 as a guide to assigning a learning approach according to the applicable *a priori* code. Her task was to code the transcript according to the *a priori* codes and the learning approach that they indicated. When we compared our respective results, we found few differences in the assignment of *a priori* codes and learning approaches, which were easily reconciled.

3.6.4 Limitations to This Study

A possible disadvantage to the constructivist approach was with the influence of the researcher on what was reported as results, especially in the case of interview data (Mojtahed, Nunes, Martins & Peng, 2014). However, I overcame this disadvantage by asking the I**nterviewees** to verify the interview transcripts, and enlisted one or more reviewers to code the data to mitigate potential researcher bias in coding. In addition, the participants in each study sample were those assigned to instructors other than me in order to minimize research bias and conflicts of interest. This was the reason why the **Interview Volunteers** group, from which the **Interviewees** were selected, did not contain all of the members of the **Interview Pool** (See Table 3.2).

This study was also limited by its time frame, institutional space, courses that the members of the study population were currently taking, and their prior academic preparation, all of which were unchangeable. In addition, more than 95% of the Study Sample participants and

98% of the Interviewees responded that they had taken Advanced Placement or International Baccalaureate courses, so that the Study Samples were, perhaps, less heterogenous in terms of prior academic background than originally expected. This affects the trustworthiness of the results in its applicability to first-year programs at other institutions. Because of the heavy emphasis on testing within the AP and IB programs, it would also not be surprising to find that the study participants used either the surface-achieving or deep-achieving learning approaches more often than either the surface or deep approaches. A possible future study could further explore the issues associated with testing and its effect on learning approaches, leading to recommendations for educators to reconcile these sources for extrinsic motivation with their own desire to cultivate an appreciation for lifelong learning in their students.

Responses were also influenced by a participant's frame of mind at the time of their surveys and interview. Even though participants had consented to being interviewed, conducting an interview near the end of a semester became a competition with actual or potential distractions. However, the interviews were scheduled at the **Interviewees'** convenience, whenever possible, in order to minimize distractions.

Another limitation of this study was the prospect that one or more of the **Interviewees** might actually exhibit different learning approaches in different contexts, and that this behavior would not be captured by the data collection protocols. A lack of correspondence across survey and interview responses could arise from the sampling method that I used, which was described in Section 3.3.1. It is possible that the constraints in this sampling method were overly limiting, and that the consideration of additional survey data might have revealed a different basis for selection of the **Interviewees**. In addition, the labeling of each prospective Interviewee with an apparent learning approach might have been subject to bias, because I found it difficult to accept that a participant who selected three or more responses to their purpose for studying was responding authentically. If I were to conduct another study in the future with these survey data, I would re-word the "purpose for studying" survey question to prompt the participants to either choose the one response that was most important to them, or to rank-order the responses in order of importance.

Another factor that limited the selection of participants at risk for academic disengagement in their second year, and therefore more likely to benefit from mitigation efforts, was the availability of participants for interviews, which was constrained by consent to participate in the study, willingness to be interviewed, and the possibility of a conflict of interest if they were to be interviewed. Because there are a number of factors that may contribute to academic disengagement in the second year (see Section 2.2), it may be difficult to predict which participants would be at risk unless the second-year experiences of the Interviewees were to be explored in a longitudinal study, and their initial interview and survey data compared to other available participants, who would then be interviewed or prompted to write about their own second-year experience.

Finally, limitations introduced with the COVID-19 pandemic included the negative emotions that many members of society felt as a result of this public health emergency, as well as the fact that any person could have contracted this disease at this time and with serious consequences (Li, Wang, Xue, Zhao & Zhu, 2020; Toquero, 2020). Negative emotions could have affected cognitive functions by interfering with the ability to think clearly (Li et al., 2020). I reassured the **Interviewees** that I understood their concerns about the pandemic, which we had in common, thereby exhibiting empathy during the interviews and moderating my tone of voice when asking questions. In addition, all interviews were conducted over Zoom® rather than in person.

Data collection was also affected by the conditions imposed by the pandemic, such as the necessity to distribute surveys and conduct interviews online rather than in person. This depersonalized the process to some extent and may have resulted in a lower response rate than if I had explained the purpose of my study to the **Interviewees** and the **Study Samples** in person. This limitation was mitigated by showing respect for the Interviewees by contacting them individually to explain the purpose and anticipated outcome of my study, rather than through a mass mailing, and by emphasizing the benefits that both they and other students would gain from the knowledge generated by this study.

3.7 Ethical Issues

The confidentiality of participants was assured under this research plan, because the data were de-identified prior to analysis and the publication of results (AERA, 2011). Since I was obligated to obtain consent from the participants prior to data collection, according to American Educational Research Association standards (AERA, 2006; AERA, 2011), the demographic survey provided the opportunity for the participants to consent to be interviewed. I also assumed that the data accurately reflected the participants' responses to the survey and interview questions (AERA, 2006). Finally, all data were secured on password-protected computers and in lockable offices to protect the identity of the study participants.

The proposal for this study was reviewed by the Institutional Review Board (IRB), but the IRB determined that the study itself was not subject to IRB regulation due to a lack of generalizability based on a one-institution study space. However, the collection of study data from first-year engineering students was subject to the provisions of IRB #12-507, which provided consent and de-identification of the participants, except for the members of the Interview Pool, whose contact information was needed for interviewing. However, the Interview Pool identifying data were secured according to the protocols described above.

3.8 Chapter Summary

The research protocol described in this chapter was informed by prior studies in learning approaches and strategies, as well as by related studies containing the study of both learning approaches and strategies and the influence of reflection on both of these constructs. Two survey instruments were also included, along with an interview protocol. Analysis methods used were both quantitative and qualitative in order to identify possible trends in this population of students toward specific learning approaches and strategies, including reflective learning strategies.

My research framework was based on constructivism, with the rationale that the knowledge gained from this study was constructed between or among individuals rather than dispensed by an authority. I gained the knowledge about learning approaches and strategies among first-year engineering students through fifteen semi-structured, interactive interviews. I also “constructed” a protocol that included both common and follow-on questions for each interview, in which the follow-on questions were based on the initial responses to the common questions about the purpose of studying, the quest for understanding, most useful learning strategies, the role of self-questioning, and the usefulness of study groups for learning.

The data gained from the interviews was “unpacked” and explored using *a priori*, pattern and comparative, coding. Each coding method revealed a set of categories for the phenomenon of learning approaches and strategies among first-year engineering students (Akerlind, 2005; Hoffding & Martiny, 2015). A subdivision of the categories represented by the *a priori* codes revealed how a particular learning strategy could be influenced by any one of the four underlying learning approaches, depending on the context in which it was employed and the goal or need that it fulfilled. This subdivision allowed these categories, and therefore the phenomenon of learning approaches and strategies, to be described more completely and authentically (Bevan, 2014; Hoffding & Martiny, 2015). Equally important was for me to set aside my own knowledge and beliefs about learning approaches and strategies through "bracketing" (Bruce, 1994) and adopt a mindset of zero prior knowledge (Bevan, 2014).

Knowing that the results from large samples of a population are more indicative of that population than small ones, the interviews were preceded and succeeded by End of Semester Surveys that contained additional questions about learning strategies, with an emphasis on reflective strategies in four types of courses: ENGE, science, math, and non-technical. Fourteen of the fifteen **Interviewees** also participated in both **Study Samples.** The **Study Sample Fall 2020** and the **Study Sample Spring 2021** each contained approximately 1,200 participants, or 60% of the study population of approximately 2,000 first-year engineering students. Therefore, the End of Semester Survey results provided as realistic a description of the study population's responses to the survey questions as could be expected.

Finally, the research protocols described in this chapter were developed in alignment with the underlying problem, research question and sub-questions, conceptual framework, and anticipated scope of results. The results of this study have the capacity to inform first-year engineering educators of their students' probable tendencies toward the surface, surface-achieving, deep-achieving, and deep learning approaches within the variety of contexts present in their courses.

4.0 Results

4.1 Introduction

This chapter presents data that address my research question and its sub-questions in the form of a summary of the learning approaches and strategies used by fifteen first-year engineering students, along with reflection-related survey responses collected from approximately 1,200 students. Results were derived from the use of both qualitative and quantitative methods of analysis, as described in the previous chapter.

My research question and its sub-questions are as follows:

- How do first-year engineering students describe their learning approaches and strategies?
  - How do first year engineering students customize their learning approaches and strategies among their courses?
  - How do first year engineering students employ reflection as part of their learning strategies?

One of the most interesting findings was the fact that many **Interviewees** stated that their overall purpose for studying was to achieve high grades by preparing for tests (a surface-level approach), and yet the learning strategies that they used reflected a deeper engagement with their course material than one would expect from students whose sole focus was on grades. However, this deeper engagement with learning was less commonly influenced by interest in the subject matter itself than by a need to develop a self-perceived level of conceptual knowledge in order to achieve high grades on tests.

Another result of this special interest was the use of reflection as a variety of cognitive and metacognitive learning strategies, which both the **Interviewee** and **Study Sample** groups exhibited in their responses to the reflection-related survey questions adapted from the Kember reflection model (Kember et al., 2000). The Kember model can be used in a linear manner, where the initial stages represent a more limited reflective or intellectual perspective than the latter stages, and students "progress" through the stages as they gain experience and maturity. However, I used it to describe the use of reflection by first-year engineering students in various combinations of stages. Nearly all of the **Interviewees** applied learning approaches and strategies from more than one stage to the requirements and contexts both within and among courses.

My research question addressed the need to explore how first-year engineering students describe their learning approaches and strategies, using a sample of fifteen participants who had volunteered for semi-structured interviews, along with available data from a **Study Sample** of approximately 1,200 first-year engineering participants. Most of the **Interviewees** used a combination of surface and deep approaches and their corresponding strategies. There was a heavy emphasis on earning high grades as the purpose of studying, which implies a limited amount of engagement with the course material through a surface approach. However, many of the **Interviewees** described deep learning strategies, such as extensive practice and self-questioning, in order to learn on a conceptual level, especially in their technical courses, which they identified as the means to earn high grades.

My first sub-question focused on how the **Interviewees** customized their learning strategies among their courses. Differences existed between the learning strategies used in technical and non-technical courses. For example, **Interviewees** reported that their technical courses required repeated practice in solving problems and relating concepts to examples, indicating meaningful engagement with course material, while non-technical courses were regarded as little more than GPA contributors for which the **Interviewees** were “studying for the grade.” Results that inform both my research question and first sub-question are presented together in Section 4.2.

My second sub-question explored the use of reflection as a learning strategy, for which both the **Interviewees** and the **Study Sample** completed eight reflection-related survey questions for each of four courses at the end of each of two semesters. The Spring 2021 results revealed an increased necessity to think about course material and exercise the metacognitive skills of self-questioning and self-monitoring for more extensive understanding and performance improvement. This increase was more pronounced for Science and Math courses than for ENGE and Non-technical courses. Section 4.3 addresses this sub-question by linking both **Interviewees** and **Study Sample** responses to the various stages of Kember’s reflection model, and the extent to which both the Interviewees and the Study Sample participants agreed or disagreed in their responses to the reflection-related survey questions (Kember et al., 2000).

4.2 Learning Approaches and Strategies Revealed Through Coded Interviews

The seven interview questions contained two questions that focused on the products of studying, as expressed by Biggs as “What do I want to get out of this?” and five questions about the process of studying, which Biggs stated as, “How do I get there?” (Biggs, 1988). While all fifteen **Interviewees** answered each question, several of their responses pertained to more than one question and were analyzed accordingly. For example, if a response mentioned self-questioning as a learning strategy, this response was analyzed under both the question about self-questioning and the question about how to handle difficult material.

Certain approaches and strategies were found to be similar for both technical and non-technical courses, while others were dissimilar. Examples of the use of reflection are also included, most often revealed through metacognitive strategies such as self-monitoring, self-questioning, and self-evaluation of learning.

After open coding and pattern coding revealed specific learning strategies and how they were different for technical vs. non-technical courses, *a priori* coding was used to categorize these responses according to a wide variety of prior studies found in the literature. The *a priori* codes and their corresponding learning approaches are shown in Table 3.8 in the previous chapter. Table 3.8 was also used to relate the **Interviewees**' open-coded responses to their approaches to learning, as shown in Tables A.1 through A.7 in Appendix A.

A summary of the learning approaches for each **Interviewee**, question and response is given in Table 4.1 on the next page. This table was derived from the tables in Appendix A by compiling the frequencies of surface, surface-achieving, deep-achieving, and deep responses. Although certain **Interviewees** provided a larger number of unique responses than other **Interviewees**, each **Interviewee** was assigned an overall learning approach, relative to other approaches, for each of two types of interview questions, i.e., product-related and process-related (Biggs, 1988). These results are also depicted graphically in Figure 4.1.

Figure 4.1 shows the predominance of the surface-achieving approach for the products of studying, i.e, purpose of studying and metrics for understanding, and the predominance of the deep-achieving approaches for the processes of studying. However, the details in Table 4.1 illustrate how both approaches could be used in either series or parallel, depending on how learning strategies and chosen and applied. These choices are often influenced by context and the availability of resources.

Table 4.1: Learning Approaches for Each Interviewee, Question, and Response
(Key: S = Surface; SA = Surface-Achieving; DA = Deep-Achieving; D = Deep; repeats correspond to multiple responses)

	Product-Related Questions		**Process-Related Questions**					
Name	Purpose for Studying	Attain Understanding	What to Study Next	Most Useful Methods	Handle Difficult Material	Self-Questioning	Study Groups	Totals
John	DA, DA	D, DA	SA, DA, DA	SA, D, D, DA	D, DA	SA, D, DA	DA, DA	3SA, **10DA,** 5D
Michael	SA, D, D, D	D, D, DA	D, DA, DA, DA	D, D, DA	D, DA, DA	D	D, DA	1SA, 8DA, **11D**
Hillary	D, D, DA, DA	D, DA, DA	D, D, DA, DA	D, D, DA, DA	D, DA, DA	D, DA	D, DA	12DA, 10D
Valerie	D, DA	SA, SA	SA, SA	SA, SA, DA	D, D, DA	D	SA, SA	**8SA**, 3DA, 4D
Nathan	SA, SA, D	D	S, SA	SA, SA, SA, SA	SA, DA	D	DA, DA	1S, **8SA**, 3DA, 3D
Micah	SA, D	SA, DA	SA, DA	SA, SA, SA	D, DA, DA, DA	D, DA	DA, DA, DA	6SA, **9DA**, 3D
Larry	SA, DA, DA	SA	SA, DA	SA, D, DA, DA, DA, DA	D, D, DA	SA, D, DA	DA, DA	5SA, **11DA,** 4D
Keith	S, SA, SA, D	SA	SA, SA	D, DA, DA, DA, DA	SA, DA	SA	SA	1S, **8SA**, 5DA, 2D
Adam	SA, DA	D, D	D, D, DA	SA, D, DA	D, DA, DA	D, D, DA, DA	D, D, D	2SA, 7DA, **11D**
Pete	S, SA, DA	DA	SA, SA, D, DA	SA, SA, SA, SA, SA	D, DA, DA, DA	D, D, DA	DA, DA	1S, **8SA**, 9DA, 4D
Jeremy	DA, DA	DA, DA	SA, DA	SA, D, DA	SA, DA, DA	D, DA	SA, DA	4SA, **10DA**, 2D
Mark	S, SA	SA	SA, SA, DA	SA, SA, D	SA, DA, DA, DA	S, DA, DA	SA	2S, **8SA**, 6DA, 1D
Lori	S	D	SA, DA	DA, DA	SA, DA	SA, DA	SA	1S, **4SA**, **5DA**, 1D
Kira	SA, D	D	DA	DA, DA	SA, D	DA	DA	2SA, **5DA**, 3D
Michelle	SA	DA, DA	SA, SA	D, D, DA, DA, DA	SA, SA, DA, DA	D	SA	**6SA**, **7DA**, 3D
Totals:								
S	4	0	1	0	0	1	0	6
SA	14	6	16	18	8	4	7	73
DA	11	10	15	22	25	14	16	113
D	11	9	7	13	12	12	6	70

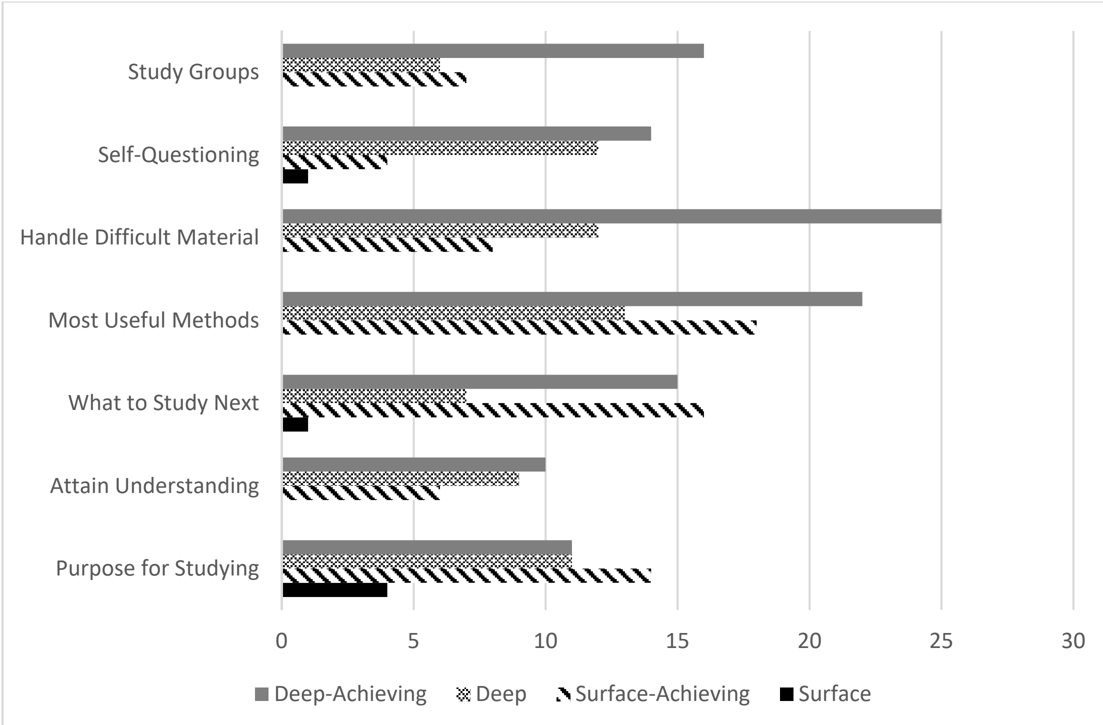

Figure 4.1: Frequency of Learning Approaches for Responses to Each Interview Question

The following sections contain descriptions of each of the interview questions, as well as direct quotes and summaries of responses by selected **Interviewees** to provide authenticity. Responses were grouped according to the product-related questions, i.e, purpose for studying and metrics for understanding, and the process-related questions, i.e., planning, most useful methods, difficult material, self-questioning, and study groups.

4.2.1 Product-Related Approaches to Learning Revealed by a priori and Pattern Coding

Product-related learning strategies include identifying a purpose for studying, and determining a metric for the attainment of understanding. The **Interviewees** each identified a purpose or goal for studying and how they determined that they had achieved understanding or comprehension of course material. Their coded responses revealed product- or goal-related learning strategies that exemplified one or more learning approaches, as shown in Tables A.1 and A.2 in Appendix A. The *a priori* codes shown in Table 3.8 were applied to each item of open coded data, along with the learning approach whose description most closely corresponded to the intent of the response.

Results for the purpose of studying fell into two categories: mastery vs. performance. Illustrations of each approach appear in the following section, with direct quotes from interview transcripts for emphasis. If an **Interviewee**'s purpose for studying was based on mastery, goal orientation theory indicates that they seek to develop competence in order to satisfy their own interests or internal standards (Pintrich, 2000). If the **Interviewee**'s goal was performance rather than mastery, it means that they sought to develop competence against an externally-imposed standard, such as a test in which their performance would be compared to that of others through grading (Pintrich, 2000). When these two types of goals are compared to Biggs' conceptual framework, the mastery goal is related to the deep approach, and the performance goal is related to both the surface-achieving and deep-achieving approaches.

4.2.1.1 Purpose for Studying: Mastery vs. Performance

Nine of the **Interviewees** stated that their main purpose for studying was to perform well on course assignments and tests, whether in technical or non-technical courses. They described "performing well" as solving problems and answering questions correctly in technical courses and recalling facts and definitions readily in non-technical courses. These responses indicated an emphasis on performance rather than on the mastery of course material.

The remaining six **Interviewees** expressed a desire to gain mastery of course material in order to reach some level of conceptual understanding and knowledge, which they could then apply to not only test performance but also could transfer to future courses and to their careers.

These goals reflect a deep-achieving or deep approach, depending on whether the goal is short-term or long-term in nature. These six **Interviewees** also wanted to “know more” than their course materials provided.

In both cases, certain **Interviewees** also revealed that they spent more time studying subjects that they enjoyed or otherwise found to be interesting. Michael, in particular, emphasized that he worked on math assignments just to complete what was necessary, so that he could devote more time and attention to subjects that he enjoyed, found to be interesting, and/or could be more readily related to real-world phenomena that he could either see or visualize:

“I'd say probably depending on the course. For me, I feel like I like to learn a lot, so I enjoy being in school, sometimes I just want to study just to get a grade, but I do in some cases, but also some cases like, I'm in engineering, already, see? I took environmental science class and I really enjoyed it because stuff like that is interesting.”

This example illustrates the difference in learning approaches between mastery and performance by the ways in which the *a priori* code, “forming value judgments about what is learned” (see Table 3.8) is associated with a deep approach when the student’s purpose was an engagement with learning itself, as opposed to a surface-achieving or deep-achieving approach when their purpose was higher test performance.

Upon further exploration of this question, certain mastery-focused and performance-focused **Interviewees** expressed a desire to attain conceptual knowledge, because they believed that it would increase their success on tests in which the problems or questions were conceptually similar to what they had viewed in class or in homework. For example, John, a proponent of mastery but a practitioner of performance, had been relying on just applying the correct formula to a test problem and then struggled on a test in which the problems were constructed to concurrently draw from a number of fundamental concepts:

“I've very recently found out it's very easy to do in math and physics because it's like here's a problem. Just plug in, use the correct formula, then you can just run through it easily. I just bombed an ECE exam yesterday. I got to completely change all my studying habits for that course because what I was doing clearly did not work.”

John later realized that he needed to develop a deeper level of understanding of these concepts, as well as the ability to apply them under a time constraint. John’s original intent was high test performance in his major-related course, by applying the “monitoring and evaluating the use of strategies” learning strategy (see Table 3.8), which reflects a deep-achieving approach; however, he was actually using a surface-achieving approach, thinking that it would be sufficient for success.

4.2.1.2 Indicators of Understanding for Mastery or Performance

Table A.2 contains responses to the second product-related interview question, in which **Interviewees** were asked how they knew that they understood the material in their courses. The most common indicators were the ability to solve technical problems without using notes or asking for help and the ability to teach other students effectively. For certain **Interviewees**, the desire to help peers to understand material motivated them to learn it more thoroughly. Additional conditions for understanding included the confirmation of correct answers to Technical problems, the fact that some subjects are easier to understand than others, high grades on quizzes, visualization with real-world examples, and the ability to clearly explain a concept orally. This final example is also a form of self-teaching, as in the following scenarios by Adam and Michael:

Adam: "…your comfort with a concept idea, your ability to, I like to try and read to teach something that definitely helps. Especially with math. Like my roommate will ask me about a concept and me reviewing it, saying, explaining it out loud to him. That definitely helps me."

Michael: "Or in physics, what does each variable represent?"

The ability to teach others effectively requires a greater engagement with course material than a student who uses a surface approach would be willing to pursue. It is often aided by a genuine interest in the subject matter through a deep-achieving or deep approach, as well as a desire to help other students.

For both technical and non-technical courses, Lori described her attainment of understanding in terms of recognizing patterns in knowledge, as follows:

"I think in a STEM class, it's always kind of just knowing why something builds up to something else, because I feel like a lot of it is just so much previous information is now leading to this new thing. So, I feel like if I understand, I guess the basics of something, then I can apply it to something larger. So that's kind of how I, if I understand the basics, that's kind of how I know I understand the full picture.

So, and then I guess in a non-STEM sort of class, it's sort of, I guess, for example, in history, it would be like knowing why some event led to some other event or something like that. So, I guess it is understanding more of the previous knowledge and stuff."

The way that Lori described the recognition of patterns in knowledge and how they enhance understanding was also expressed by Valerie through a slightly different example. Valerie knew that she understood a technical concept when she could apply it in multiple different ways on a practice test. She also described how additional course-provided materials helped her to understand topics and their concepts more thoroughly, by providing additional practice, and observed that many students in her class didn't take advantage of these materials and suffered accordingly when a deeper understanding was required.

Both Lori and Valerie sought and identified patterns in knowledge using a deep-achieving or deep approach. Valerie's example could be considered deep-achieving, per Table 3.8, because of her desire to apply conceptual knowledge to a variety of problems on technical course tests. Lori expressed the discovery of patterns and relationships in knowledge in both technical and non-technical courses; her approach was deep rather than deep-achieving (see Table 3.8) because this type of insight emerges from a greater engagement with learning than test preparation would ordinarily require.

4.2.1.3 Summary of Responses to Product-Related Questions

The two product-related questions about the purpose for studying and metrics for understanding yielded results revealing underlying learning approaches focused on either mastery or performance. In the former case, a deep approach was revealed when a student's purpose was an engagement with learning itself, while a performance-based purpose indicated a surface-achieving or deep-achieving approach.

Responses for the attainment of understanding followed a similar pattern of mastery vs. performance, but the differences between these two goals was less clear. **Interviewees** knew that they understood technical course material when they could solve problems without help from notes, peers or instructors, which is again focused on performance, while the ability to teach others effectively required a more thorough understanding of concepts and how to apply them than a performance goal might require.

4.2.2 Process-Related Approaches to Learning Revealed by a priori and Pattern Coding

Process-related learning strategies included planning, useful methods for learning both easy and difficult course material, self-questioning, and the use of study groups. All of these strategies involve how studying is done, rather than what to study and why. The following subsections address the **Interviewees**' responses to each of the five questions relating to the process of studying. Coded responses for process-related learning strategies and exemplified learning approaches are shown in Tables A.3 through A.7 in Appendix A. The *a priori* codes shown in Tables 3.7 and 3.8 were applied to each item of open coded data, along with the learning approach whose description most closely corresponded to the intent of the response. In some cases, the judgment to assign a particular approach to a response depended on the context of not only that response, but of responses to related questions.

4.2.2.1 Planning for Study

The strategies that the **Interviewees** used when they planned how and what to study next are shown in Table A.3. Because meeting deadlines and class schedules are important aspects of being a successful college student, it was not surprising to find that all of the **Interviewees** paid close attention to homework due dates, test dates, and class times on any given day when planning what and when to study.

For Nathan, this was the only strategy that he used to decide what to study next. He considered planning in advance to be pointless because he "could never be 100% accurate." A primary focus on deadlines was also expressed by Valerie, Larry, and Jeremy. These four **Interviewees** took a surface-achieving approach, because they knew that they would have to meet deadlines in order to achieve satisfactory grades.

Having identified and recorded due dates, the remaining **Interviewees** described how they set priorities for what to study next. Six would begin with their most difficult subject(s), due to an urgency to attend to them for success in a course, while another four began with their easiest, most enjoyable, or most interesting subjects, in order to allow more time for the difficult ones. A third method for setting priorities, based on the relative value of a course to one's career or personal interests, was described by Michael as beginning with a "must do" course, such as math, and then moving on to subjects that he enjoyed, were more useful for his career (in his opinion), and for which he wanted to devote additional non-rushed time and attention:

> "I feel like so I tried to make like a daily plan for myself, [such as] like a Word document. I'll say like the date and then I'll go like chronologically throughout the day. So, I have decided that, if I have a class at 3:30, in-between I'll work and eat lunch and I'll do work afterwards. So, I mean, I feel like the work I try to start my day with my math and STEM stuff because I'll be most awake for it. Something just to get out of the way…. Then later that day I can do English work or katz or something I find more enjoyable, and my Nitwit®."

Michael's approach was deep, according to Table 3.8, because he expressed a strong engagement with learning when he decided what to study next. Similarly, John, Micah, Pete, and Kira often chose to study their most difficult subjects first, with the intent to achieve understanding not necessarily for its own sake, but because they knew that they would be tested on it. Setting a priority on what to study based on what will be tested is an achieving approach; in their case, it would be deep-achieving because these **Interviewees** expressed a desire for some level of understanding on a conceptual level. At the same time, Kira often planned according to her sense of urgency, which could arise from either impending deadlines, difficulty of the course material, or both.

According to Hillary and Michael, the allocation of time to tasks was another important factor in setting a study schedule. Knowing that these were estimates, i.e., that it was difficult to know exactly how long a task would take (which kept Nathan from planning at all), Hillary and Michael would add "buffer time" to their schedule to accommodate unexpected events or allow for non-academic activities that they wanted to pursue as a break from studying. Hillary, Adam, and Larry also recognized the value of taking a break from studying by spreading their study time and material over a number of days, rather than in one or two marathon sessions. Hillary described this strategy as follows:

> "So, like a math assignment, you do the lecture videos, you do the assignment, let's say it's due on Wednesday, so I'll do it on Tuesday. And it's like I have the buffer time in case I falter a little bit. But so, like bigger assignments, let's say physics labs that are due on

Sundays, those I'll do the time increments. I'll do like an hour one day, an hour another day."

These **Interviewees** described how they consciously allocated their resources, such as time, among their course demands. The specific ways in which they did or did not allocate time could exhibit any of the four learning approaches.

When asked how to decide what to study next when two subjects seemed to have an equal sense of urgency, John and Keith used opposing tiebreakers: the former assessed the risk of failure on an assignment or test (a variation of "most difficult" subject), while the latter chose to study the subject that he enjoyed the most:

John: "I would definitely first look at my grades in each class to see [in] which one I could potentially fail the assignment and be alright. Assuming I can't fail either assignment and be alright, I would start with the more major related class first."

Keith: "If everything's about the same, I'll probably just do what I enjoy most so I feel more motivated to keep doing the homework."

Mark also followed John's approach but added the judgment that he would prioritize his technical subjects because, at least in his experience, they were more difficult than non-technical courses. In this example, both John and Keith were using a surface-achieving approach, per Table 3.8, while Mark used a deep-achieving approach based on his assessment of difficulty across all or most of the technical courses that he had taken.

4.2.2.2 Most Useful Methods, Especially for Difficult Course Material

Tables A.4 and A.5 in Appendix A contain the strategies that the **Interviewees** considered to be the most useful and their strategies for dealing with difficult course material, respectively. Several forms of active learning through hands-on problem solving with technical practice problems and practice tests were commonly mentioned. These practice instruments were generally supplied by the course instructor from a pool of test problems and questions that were modified or simply rotated from one semester to the next. Many of the **Interviewees** considered these practice problems and practice tests to be highly useful for graded test preparation.

Referring to the descriptions of this strategy with respect to different learning approaches in Table 3.8, both the deep-achieving and deep learning approaches are apparent when a student works practice problems and tests beyond those supplied by the course instructor. This action shows initiative by the student to further explore the knowledge represented by the given subject matter, which is a major difference between the surface and deep learning approaches.

An additional method was practice through self-teaching, especially with technical courses, through a willingness to explore various conditions, tools and techniques to find out what does and does not work. This form of active learning was helpful to Michael, Larry, Pete, and Nathan in mastering software programs and working their practice problems, and by Jeremy in learning a foreign language. Pete succinctly expressed the benefits of active learning:

> "Even though you could watch everybody solve every single problem you're not going to do as well when you go to do your own work."

According to Tables 3.7 and 3.8, self-teaching is an aspect of the self-directed learning strategy. These students used a deep approach when applying this strategy because they expressed a genuine interest in learning how to use the given software or foreign language in their descriptions.

For non-technical courses, online practice instruments were sometimes available, such as Nathan's use of Quizlet®, an online self-testing tool, as an aid to memorization. While the memorization strategy is often considered to be indicative of a surface approach, it can also include a search for meaning if pursued through a deep or deep-achieving approach. Nathan used Quizlet® in a deep-achieving context to study for his history course because he was also interested in learning the meaning of terms as an aid to memorization and test preparation, which is one of the purposes for using Quizlet® (Glotzbach, 2021).

For others, re-reading non-technical lecture notes and an available textbook were often employed, especially with difficult material. In addition, Valerie and Lori would often practice with difficult material by re-writing facts and other information many times, which they also did for technical formulas, using a surface-achieving approach. Michelle went a step further by writing her own technical study guide, which includes analysis and synthesis of course material using a deep approach (see Table 3.8, Note-taking strategy).

Along with straightforward material, difficult material was also handled by dividing it into components, working with each one, and then synthesizing them back into a "big picture" by John, Pete, and Larry. In this way, these **Interviewees** could then identify relationships among the components, which is part of a deep-achieving or deep approach, depending on context. Taking this one step further, Pete, Larry, Kira, Lori, Michael, and Adam could detect certain recurring patterns in knowledge, which led them to conclude that knowledge is cumulative and that new knowledge is often built upon prior knowledge, whether in a technical or non-technical subject. The discovery of patterns in knowledge is another benefit of the use of reflection to aid metacognition while studying.

An example of the demand to retain knowledge for future use in dealing with difficult material was also described by Adam by using fundamental mathematical formulas first learned many years ago, leading him to assert that engineering students should “refresh” their knowledge of what they had learned on a regular basis, to enable recall for future courses:

> "And I guess like looking back on different things from the past integrate into newer concepts that maybe make it more difficult can also help because everything builds upon each other, like addition, subtraction, multiplication that doesn't leave. So, if you're not good at maybe like remembering the unit circle for something may be a little slower at calculating like a question that involves sine or cosine, staying refreshed on previous material can also make it easier to understand the more difficult material."

In this example, Adam was using a deep approach of comparing new knowledge to prior knowledge using reflection, as indicated in Table 3.8.

When it was necessary for the **Interviewees** to seek additional help with difficult material, ten of the fifteen **Interviewees** would first try to handle the material on their own before seeking help from other individuals or groups. Their usual order was to seek help from textbooks and notes first, then from instructional websites and their videos, and finally from peers or instructors. The remaining five **Interviewees** relied on other individuals as their first or primary source of help.

When dealing with difficult material in particular, Larry also found it helpful to relate it to real-life examples as a way to visualize the material in action, which employs a reflective strategy and a deep-achieving or deep approach. Micah and Kira would try using a different series of steps to explore it, and Hillary and Valerie realized that it might take longer to understand something that is difficult, but that understanding can almost always be attained. These last four students exhibited a willingness to persist in their quest to understand difficult material, which is also a major difference between the surface and deep approaches. It may also involve reflection to assess the level of difficulty and identify a need for persistence.

4.2.2.3 Self-Questioning

The **Interviewees** asked themselves the following self-questions as they studied technical course material:

- Do I understand how to do this problem?
- Do I understand the theoretical aspects?
- How well do I know this material for the test?
- What things did I learn earlier that might make this less difficult?
- How could this concept be applied in the real world?
- Can I teach this to someone else?

For non-technical courses, self-questions were also focused on understanding the course material, but in a more general sense and occasionally with the identification of real-world examples. However, since the **Interviewees** indicated a much lower requirement for efficient and accurate problem solving in non-technical courses, they used the self-questioning strategy less often than in technical courses. This was a result of the underlying intent of the questions shown above, which was to meet testing/assessment requirements rather than express curiosity.

For either technical or non-technical courses, the abovementioned questions related to one basic need: "How can I learn this better?" Several **Interviewees** also described how the search for patterns, connections, and relationships among the items of knowledge helped them to compare what they were learning to their prior knowledge as a way to reinforce meaning and retain their new knowledge by using new facts and information to expand their existing body of knowledge. Once again, the comparison of new knowledge to prior knowledge as well as the recognition of patterns and relationships can be derived from reflective learning strategies and are indicative of a deep-achieving or deep approach.

Among the **Interviewees**, only Mark stated that he did not consciously ask himself questions while studying. However, he did check the results of his work against the given solutions to practice problems and would troubleshoot problems with incorrect answers to find the sources of mistakes. Mark was using a deep-achieving approach in these cases because his goal was correcting errors that he might make on a test, rather than questioning whether his results made sense, according to the descriptions in Table 3.8. However, his prior responses indicated a less inquisitive approach to his course material than those of other **Interviewees**, by focusing almost exclusively on test performance rather than interest and/or engagement.

4.2.2.4 When and How to Study with a Group

Most of the **Interviewees** agreed that a small study group could be effective as long as everyone in the group was focused and exhibited similar approaches to studying. Nearly everyone viewed large groups as potentially distracting. Hillary even decried the behavior of study groups of any size in this way:

> "I find a lot with study groups, people are very elitist about what they know and what they think they know. I know a big thing, in especially the computer science discourse, is that people go in and they act like they know everything. And then you go do the assignment and they're like, Oh, it's going to take a long time, it's going to be really hard. I would be scared if I were you and then you go in and you're like, I mean, it was hard but it wasn't like, you know, you need to intimidate me."

Hillary was by no means a slacker. Her responses reflected her views that she was serious about her studies and also asserted that she knew that she would have to work harder than others in order to succeed. This is an example of self-evaluation of learning on a continuous basis, which is part of the group of self-directing and self-regulating learning strategies shown in Tables 3.7 and 3.8. What Hillary meant by "success" was not limited to performance on tests, but to her own assessment of how easily or quickly she could learn, which indicates a deep rather than a deep-achieving approach.

The benefits of studying with a group, whether large or small, were that the participants could both receive help and give help, both of which seemed to add to their self-confidence. However, most **Interviewees** who participated in study groups favored smaller groups over larger ones, because it was easier to maintain focus without distraction.

Michael, Nathan, Valerie, Jeremy, and Pete mentioned the study groups also offered the opportunity to teach others and thereby reinforce one's own learning. The context for each of their responses was preparation for tests and projects, which is a deep-achieving rather than a deep approach. However, the opportunity to “bounce ideas off each other” was useful for correcting misconceptions and reinforcing conceptual knowledge, according to Nathan, Micah, and Pete, and could be labeled as a deep approach because its focus was on mastery of knowledge rather than on test performance.

Another way to reinforce conceptual knowledge with a study group was described by Larry as a two-step process:

> “I found them to be decently helpful, more so towards the beginning and the end of studying, if that makes sense. So, I'll get together with a group and we'll go over, say, it's something like chemistry. We'll talk about the general topics, keywords, key things, and so we get a general idea of what we need to be studying. And then I like to do my own reflection so I can make sure I'm getting all these words memorized. And then the end of it is whenever you're working with the groups again, and you're just making sure that everything that knows the same level and everything, and that you don't have any holes in your logic and everything.”

Adam’s response was equally thoughtful when he stated that a study group can be effective if it is focused on helping everyone with understanding. However, Adam’s experience with study groups revealed that many functioned in name only, such that he found it more beneficial to employ self-testing as part of studying alone.

4.2.2.5 Summary of Responses to Process-Related Questions

The process-related questions included a wide variety of contexts for the selection of learning approaches and strategies, from planning to most useful methods, handling difficult material, self-questioning, and participation in study groups. Planning was influenced most heavily by class schedules and deadlines, although a few **Interviewees** balanced this source of urgency with their own interests and preferences. For technical courses, the most commonly used methods were practice with solving problems and teaching others about the underlying course concepts to enable them to solve problems on their own, while memorization, note taking, and online practice with flashcard programs were mentioned most often for non-technical course material.

Self-questioning was focused on individual perceptions of understanding course concepts in a quest for competence, whether the goal was satisfaction with attaining mastery or confidence about future test performance. Study groups were considered worthwhile if they were small and contained members with similar learning approaches, as well as offered the opportunity to teach others and thereby reinforce one's own learning.

4.2.3 Similarities and Differences in Learning Approaches Exhibited by Responses to Product-related and Process-related Questions, Revealed by Comparative Coding

The total numbers of product-related learning approaches indicated by the **Interviewees**' responses appear at the bottom of Table 4.1 for each interview question. While the purpose for studying responses were more or less evenly divided among the surface-achieving, deep-achieving, and deep approaches, the responses to the understanding question indicated greater use of the surface-achieving and deep-achieving approaches than of either surface or deep. The

Interviewees wanted to understand their course material and justified this desire in terms of grades rather than on the acquisition of knowledge (Biggs, 1988, 1999).

Regarding the **Interviewees'** responses to process-related questions, i.e., planning, most useful methods, difficult material, self-questioning, and study groups, Table 4.1 totals show that, for the purpose of studying, a more or less even distribution among the surface-achieving, deep-achieving, and deep approaches. For planning and the most useful learning strategies, there was a greater variation among the surface, deep-achieving, and deep approaches, and a greater tendency toward the deep-achieving and deep approaches for difficult material, self-questioning, and study groups, along with strategies for deeper engagement, such as repeated practice, interleaved practice, and the metacognitive strategies of self-monitoring and self-questioning (Ambrose, et al., 2010; Crede & Kuncel, 2008; Karpicke, 2009). See Figures 4.2 and 4.3 for similarities and differences in the frequency of learning approaches.

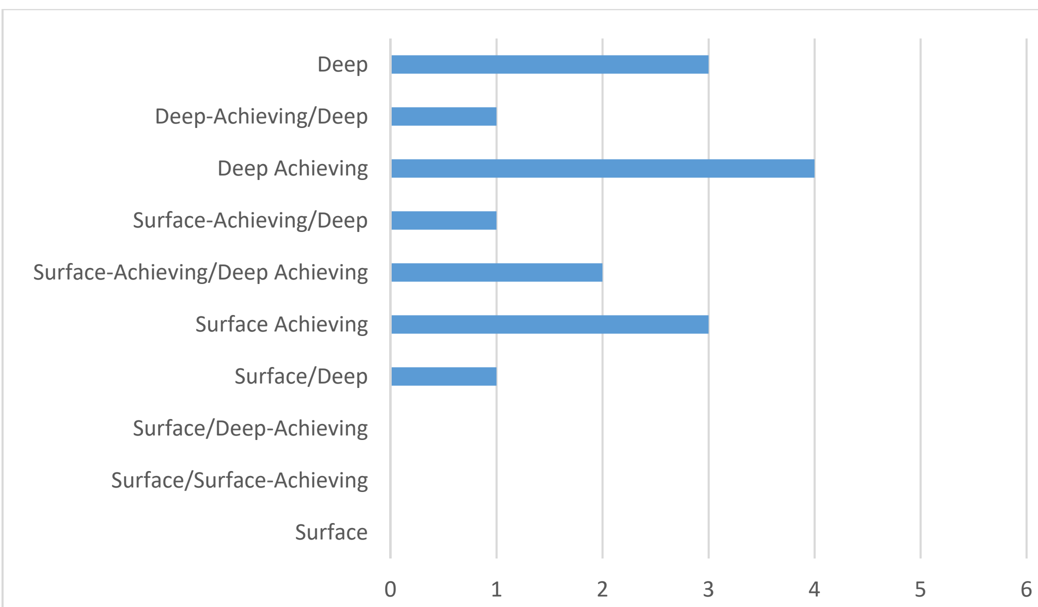

Figure 4.2: Frequency of Learning Approach(es) for All Product-Related Interview Responses

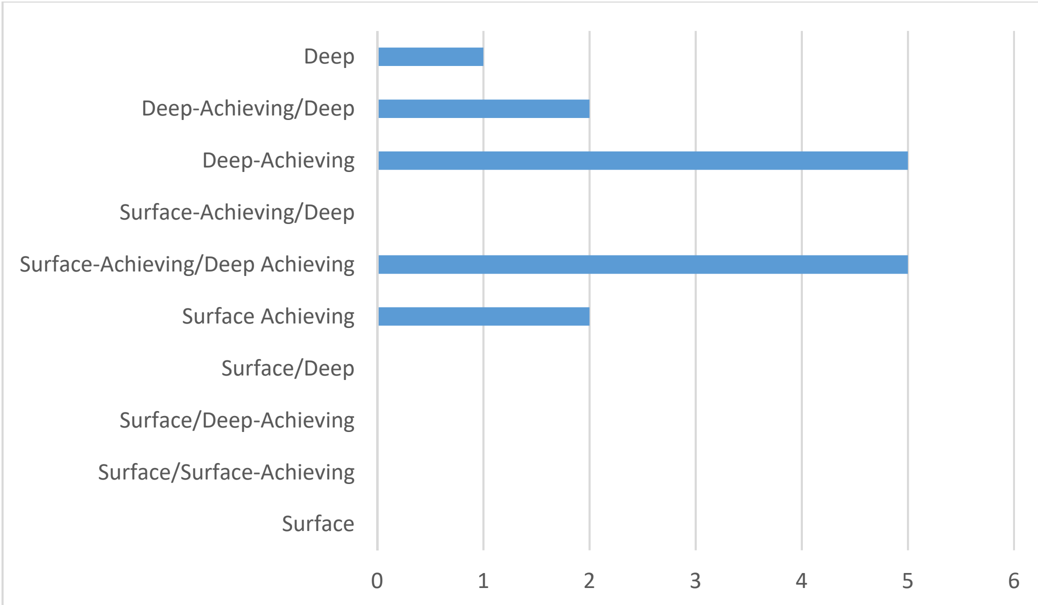

Figure 4.3: Frequency of Learning Approach(es) for All Process-Related Interview Responses

Table 4.2, on the next page, shows that only four **Interviewees** used a consistent learning approach, or combination of approaches, for all or nearly of their responses. It was more common for **Interviewees** to apply learning strategies with underlying approaches driven by the requirements and context of the learning task, such as using a surface approach when a course was less important to their intended major program and their grade was not in jeopardy, or a deep approach when they were genuinely interested in the course material for its own sake.

Table 4.2: Individual Learning Approaches, According to Product-Related and Process-Related Responses

Key: S = Surface; SA = Surface-Achieving; D = Deep; DA = Deep-Achieving

Note: Approach preference is based on **Interviewees**' responses

Interviewee	**Product-Related Responses**	**Process-Related Responses**	**Overall Approach Preference**
John	DA	DA	Same approach for both product and process
Hillary	D/DA	D/DA	Same approach for both product and process
Adam	D	D	Same approach for both product and process
Jeremy	DA	DA	Same approach for both product and process
Michael	D	D/DA	Overall approach is more heavily D than DA
Valerie	SA/DA	SA	Overall approach is more heavily SA than DA
Nathan	SA/D	SA	Overall approach is more heavily SA than D
Larry	S/DA	DA	Overall approach is more heavily DA than SA
Keith	SA	SA/DA	Overall approach is more heavily SA than DA
Pete	DA	S/DA	Overall approach is more heavily DA than S
Mark	SA	SA/DA	Overall approach is more heavily SA than DA
Lori	S/D	SA/DA	Initial purpose related to S, but certain strategies showed depth of thought sufficient for SA or DA
Kira	D	DA	Product and process responses more or less consistent
Michelle	DA	SA/DA	Overall approach is DA, but nearly equal numbers of SA and DA strategies
Micah	SA	DA	Only **Interviewee** with a clear contrast between product and process approaches

This quote from Nathan shows how he used both a surface-achieving and a deep approach for his purpose for studying, as well as the surface-achieving approach for his most useful method for learning course material:

> "Because sometimes I just study just to get a good grade on the test, because if it's not something that I need to apply in the future, or something that I really need to retain, I just study to get a good grade, but if it's something that I know I'll have to apply throughout my career, or just something I'll be using throughout school, then I'd study for a good understanding of the material."
>
> (product-related response)
>
> "Usually or sometimes the teachers provide them [practice problems, but if not, usually I just refer to the book that there is for the course because usually there's some sort of book for the course. So I just look at the book for practice problems usually."
>
> (process-related response)

Overall, the total number of combined surface-achieving + deep-achieving approaches was greater than the total number of combined surface-achieving + deep approaches. This means that, even when the **Interviewees** appeared to be deeply engaged with learning, their reasons for doing so had more to do with grades than with the acquisition of knowledge.

4.2.4 How Well the Interviewees Represented the Study Samples

I was concerned about how well the data from the **Interviewees** represented the data from the **Study Samples**, given the following limitations in the selection of the **Interviewees**:

- Consent to allow a participant's data to be used for research purposes;
- Willingness to participate in an interview;
- Non-enrollment in any of my four ENGE 1216 sections during Spring 2021; and
- Availability for an interview.

As described in Section 3.3.1, the ENGE 1215 End of Semester Survey was administered to the study population of ENGE 1215 students in December 2020, but data were collected from only those participants who had consented to having their data used for research purposes. This meant that the **Study Sample Fall 2020** was a convenience sample, which could be subject to bias (Galloway, 2005). However, this sample of 1,223 participants represented approximately 60% of the study population and consisted of the only participants whose data were available under IRB conditions.

Still another layer of "convenience" was also applied by the conditions for data collection, because the **Interviewees** were also drawn from an **Interview Pool** of 285 participants who had not only agreed to having their data used for research, but had agreed to participate in an interview. The **Interview Pool** represented approximately 14% of the study population.

The **Interviewees** were a purposive sample of the **Interview Pool**, in which stratification was used to select **Prospective Interviewees** (Krathwohl, 2009a). Stratification was based on learning approaches emerging from responses to the question, "What is your purpose for studying in ENGE 1215?" There were three **Interviewees** with a surface approach, five with surface-achieving, five with deep-achieving, and two with a deep approach.

The **Interviewees'** responses to the purpose for studying in ENGE 1215 was compared to responses to the same question by both **Study Samples**, shown in Figures 4.4 and 4.5.

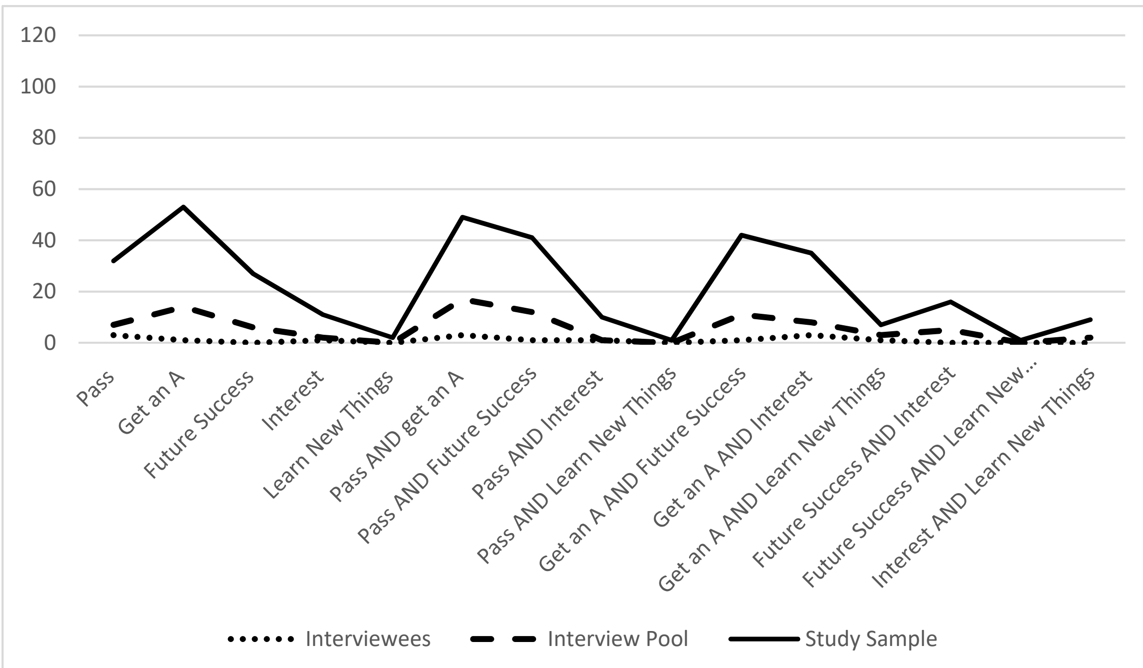

Figure 4.4: Fall 2020 Results for Purpose of Studying, Comparison among Interviewees, Interview Pool, and Study Sample, Fall 2020.

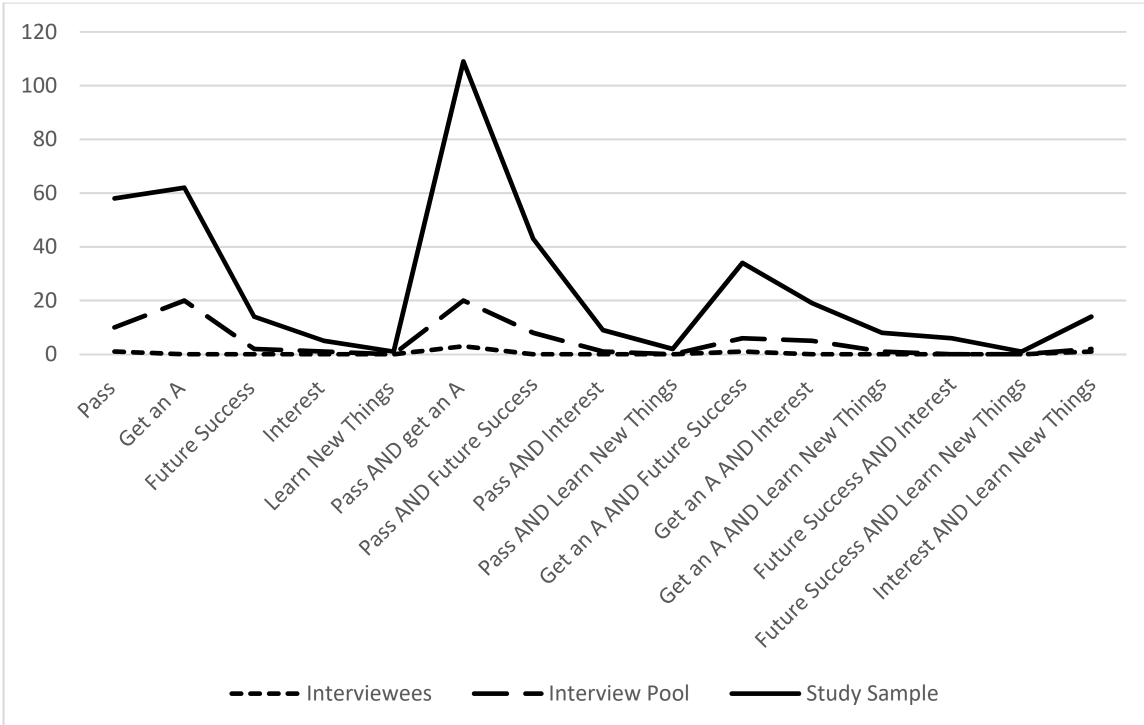

Figure 4.5: Spring 2021 Results for Purpose of Studying, Comparison among Interviewees, Interview Pool, and Study Sample, Spring 2021.

Even though it is risky to label a participant with a learning approach based on just one question in just one of their courses, there were four out of the fifteen **Interviewees** whose response to this purpose for studying question was the same as their overall learning approach, as listed in Table 4.9: Pete, Larry, Adam, and Nathan. Four others employed pairs of learning approaches in which one of the approaches matched their response to the abovementioned question: Micah, Mark, Lori, and Michelle. The remaining **Interviewees** indicated a contrasting approach between these two results; i.e., surface or surface-achieving to deep or deep-achieving.

The most frequent responses were essentially the same for all three groups, all of which included receiving an A for the course, either as a singular response or in combination with passing the course, and studying for success in future courses. This means that the sampling methods for the selection of the **Interviewees** produced an acceptable representation of the

Study Samples, even though the constraints imposed on the availability of the study participants for interviews indicated otherwise.

4.3 Reflection-Related Survey Results

All of the study participants answered eight reflection-related questions in each of the end of semester surveys for ENGE 1215 and ENGE 1216 in Fall 2020 and Spring 2021, respectively. These questions are listed in Table 3.5, along with their relationship to each stage of the Kember reflection model. The resulting data from the participants' responses are organized in this section to compare 1) **Interviewees** to each **Study Sample**, 2) similarities and differences between the Fall and Spring semesters, and 3) similarities and differences among the engineering, science, math, and non-technical courses.

The most interesting result was that while many **Interviewees** indicated different reflection stages for different courses, they also exhibited more than one stage for a particular course. This variation in the use of reflection within a course was similar to the combinations of learning approaches by **Interviewees** in Tables 4.1 and 4.2.

These original survey responses are listed in Tables B.1 through B.16 in Appendix B. Each table in this appendix contains original data for **Interviewees** or **Study Sample**, Fall or Spring, and either engineering, science, math, or non-technical course, respectively. Each reflection-related question is included in each table, along with numeric scores corresponding to Likert agreement values. The Likert agreement levels for the numeric scores are listed at the left side of each table, labeled as Data and Median scale. The median value of each question's scores was calculated and included in each table, along with the first and third quartiles and the interquartile range (IQR).

Tables 4.3 and 4.4, on the next two pages, contain summaries of the reflection-related median survey results, along with IQR values, for both the Interviewees and Study Samples in the spring and fall semesters, respectively. While the median values ranged from 2 (corresponding to Generally Disagree) to 5 (corresponding to Strongly Agree) over all of the data for both semesters, the IQR values ranged from 0 to 2.75. In general, the smaller the IQR value, the more representative the median is of the data, which indicates that 50% of the data are located within a small range between the first and third quartiles (Krathwohl, 2009b).

Table 4.3: Likert Agreement, Medians, and IQR Values for Interviewees and Study Sample—Fall 2020

Key to Stages: HA = Habitual Action U = Understanding R = Reflection CR = Critical Reflection

Key to Agreement: SA = Strongly Agree GA = Generally Agree N = Neither Agree nor Disagree GD = Generally Disagree SD = Strongly Disagree

Shading: Bold indicates IQR <1; **Bold**-*Italic* indicates IQR >2

Reflection Question		***Interviewees***			***Study Sample***		
ENGE 1215	Stage	Agreement	Median	IQR	Agreement	Median	IQR
As long as I can remember handout material for exams or assignments, I do not have to think too much.	HA	GA	**4**	**0**	GA	4	1
If I follow what the lecturer says, I do not have to think too much in this course.	HA	GA	4	1	GA	4	1
This course requires me to understand concepts taught by the lecturer.	U	GA	**4**	**0**	GA	4	1
In this course, I have to continually think about the material that I am being taught.	U	N/GA	3.5	2	N	3	1
I sometimes question the way others do something and try to think of a better way.	R	GA	4	1	GA	4	1
I often re-appraise my experience so I can learn from it and improve for my next performance.	R	GA	**4**	**0.75**	GA	4	1
This course has challenged some of my firmly held ideas.	CR	GD	2	2	N	3	2
As a result of this course, I have changed my normal way of studying.	CR	GD	2	1.75	N	3	2
Science							
As long as I can remember handout material for exams or assignments, I do not have to think too much.	HA	GD	2	1.75	GD	2	2
If I follow what the lecturer says, I do not have to think too much in this course.	HA	GD	2	1	GD	2	2
This course requires me to understand concepts taught by the lecturer.	U	GA	**4**	**0**	SA	5	1
In this course, I have to continually think about the material that I am being taught.	U	GA	**4**	**0.75**	GA	4	1
I sometimes question the way others do something and try to think of a better way.	R	N	3	2	GA	4	1
I often re-appraise my experience so I can learn from it and improve for my next performance.	R	GA	4	1	GA	4	1
This course has challenged some of my firmly held ideas.	CR	N	3	2	N	3	2
As a result of this course, I have changed my normal way of studying.	CR	GA	4	1.5	GA	4	2
Math							
As long as I can remember handout material for exams or assignments, I do not have to think too much.	HA	GD	***2***	***2.75***	GD	2	2
If I follow what the lecturer says, I do not have to think too much in this course.	HA	N	3	1	GD	2	2
This course requires me to understand concepts taught by the lecturer.	U	GA	**4**	**0**	SA	5	1
In this course, I have to continually think about the material that I am being taught.	U	GA	**4**	**0**	GA	4	1
I sometimes question the way others do something and try to think of a better way.	R	N	3	2	GA	4	1
I often re-appraise my experience so I can learn from it and improve for my next performance.	R	GA	**4**	**0**	GA	4	1
This course has challenged some of my firmly held ideas.	CR	N	3	2	N	3	2
As a result of this course, I have changed my normal way of studying.	CR	N	3	1	GA	4	2
Non-Technical							
As long as I can remember handout material for exams or assignments, I do not have to think too much.	HA	GA	4	1	GA	4	1
If I follow what the lecturer says, I do not have to think too much in this course.	HA	GA	4	1	GA	4	1
This course requires me to understand concepts taught by the lecturer.	U	GA	4	1	GA	4	1
In this course, I have to continually think about the material that I am being taught.	U	N	3	2	N	3	2
I sometimes question the way others do something and try to think of a better way.	R	N	3	1	GA	4	1
I often re-appraise my experience so I can learn from it and improve for my next performance.	R	GA	4	1	N	3	2
This course has challenged some of my firmly held ideas.	CR	N	3	2	GA	4	1
As a result of this course, I have changed my normal way of studying.	CR	N	3	2	N	3	2

Table 4.4: Likert Agreement, Medians, and IQR Values for Interviewees and Study Sample—Spring 2021

Key to Stages: HA = Habitual Action U = Understanding R = Reflection CR = Critical Reflection
Key to Agreement: SA = Strongly Agree GA = Generally Agree N = Neither Agree nor Disagree GD = Generally Disagree SD = Strongly Disagree
Shading: Bold indicates IQR <1; **Bold**-*Italic* indicates IQR >2

Reflection Question		***Interviewees***			***Study Sample***		
ENGE 1216	Stage	Agreement	Median	IQR	Agreement	Median	IQR
As long as I can remember handout material for exams or assignments, I do not have to think too much.	HA	GA	**4**	**0**	GA	4	1
If I follow what the lecturer says, I do not have to think too much in this course.	HA	GA	**4**	**0**	GA	4	1
This course requires me to understand concepts taught by the lecturer.	U	GA	**4**	**0**	GA	**4**	**0**
In this course, I have to continually think about the material that I am being taught.	U	N	3	2	N	3	2
I sometimes question the way others do something and try to think of a better way.	R	GA	4	1	GA	4	1
I often re-appraise my experience so I can learn from it and improve for my next performance.	R	GA	4	1	GA	4	1
This course has challenged some of my firmly held ideas.	CR	N	3	1	N	3	2
As a result of this course, I have changed my normal way of studying.	CR	GD	**2**	**0.75**	N	3	1
Science							
As long as I can remember handout material for exams or assignments, I do not have to think too much.	HA	GD	2	1.75	GD	2	2
If I follow what the lecturer says, I do not have to think too much in this course.	HA	N/GD	2.5	2	GD	2	1
This course requires me to understand concepts taught by the lecturer.	U	SA	**5**	**0.75**	SA	5	1
In this course, I have to continually think about the material that I am being taught.	U	GA	4	1	GA	4	1
I sometimes question the way others do something and try to think of a better way.	R	GA	4	1	GA	4	1
I often re-appraise my experience so I can learn from it and improve for my next performance.	R	GA	4	1	GA	4	1
This course has challenged some of my firmly held ideas.	CR	N	3	1	N	3	2
As a result of this course, I have changed my normal way of studying.	CR	GA	**4**	**0**	GA	4	2
Math							
As long as I can remember handout material for exams or assignments, I do not have to think too much.	HA	GD	2	1.75	GD	2	3
If I follow what the lecturer says, I do not have to think too much in this course.	HA	N/GD	***2.5***	***2.75***	GD	2	2
This course requires me to understand concepts taught by the lecturer.	U	SA	**5**	**0.75**	SA	5	1
In this course, I have to continually think about the material that I am being taught.	U	GA	4	1	GA	4	1
I sometimes question the way others do something and try to think of a better way.	R	GA/N	3.5	1.75	GA	4	1
I often re-appraise my experience so I can learn from it and improve for my next performance.	R	GA	4	1	GA	4	1
This course has challenged some of my firmly held ideas.	CR	N	3	1	N	3	2
As a result of this course, I have changed my normal way of studying.	CR	GA	**4**	**0.75**	GA	4	2
Non-Technical							
As long as I can remember handout material for exams or assignments, I do not have to think too much.	HA	GA	**4**	**0.75**	GA	4	1
If I follow what the lecturer says, I do not have to think too much in this course.	HA	N	3	1	GA	4	1
This course requires me to understand concepts taught by the lecturer.	U	GA	4	1	GA	4	1
In this course, I have to continually think about the material that I am being taught.	U	GA	4	1	N	3	2
I sometimes question the way others do something and try to think of a better way.	R	N	3	1	GA	4	1
I often re-appraise my experience so I can learn from it and improve for my next performance.	R	GA/N	3.5	1	GA	4	1
This course has challenged some of my firmly held ideas.	CR	N	3	1.75	N	3	2

The bold-highlighted cells in Tables 4.3 and 4.4 indicate responses to reflection-related responses that were more consistent than those for which the IQRs were larger. Similarly, the bold+italic-highlighted cells belonged to responses for which the IQRs described a greater spread in the data, and therefore less consistency. The highlighted cells were also limited to the **Interviewees'** data for both semesters, since the IQRs for the **Study Samples** fell outside these two ranges. This lack of very narrow or very wide variation among the data might be attributed to the size of the **Study Sample** data sets relative to those of the **Interviewees**.

The ranges of IQR>2 and IQR <1 were chosen to identify areas of greater or lesser spread, respectively, among the reflection-related survey data. The IQRs within these ranges revealed several notable trends between Fall 2020 and Spring 2021:

- General Agreement about responses for Habitual Action and Reflection strategies in ENGE 1215 and ENGE 1216;
- General Agreement about responses for Understanding strategies in science and math;
- Greater variation in responses for all strategies in non-technical courses; and
- Greatest variation in responses for Habitual Action strategies in math.

With respect to the trends shown above, several observations can be made about the variations in the use of reflective learning strategies among courses. While both the **Interviewees** and the **Study Samples** "did not have to think too much" in engineering courses (Habitual Action), both groups placed value on continuous improvement, whether in scrutinizing methods to find a "better way" or otherwise seeking clues to better individual performance (Reflection). The emphasis on Understanding in science and math, common to both **Interviewees** and both **Study Samples**, was also expressed by **Interviewees** in their interviews when they described their metrics for understanding concepts. Variations in non-technical course scope and difficulty could account for the variations among all reflective learning strategies. There was also a sizable variation in the Habitual Action strategy in math among the **Interviewees**. The variation in perceptions about the difficulty of math could be explained by the different ways in which students are taught and how they learn math in college (University of Alaska Fairbanks, 2021).

The following sections contain detailed results for **Interviewees** in the Fall 2020 and Spring 2021 semesters, followed by results for **Study Samples** during the same time frames, with comparisons between fall and spring for all four types of courses. The results for the **Study Samples** in both Fall 2020 and Spring 2021 are then presented in a similar breakdown. The final section contains a comparison of the results between the **Interviewees** and the **Study Samples** for the Fall 2020 and Spring 2021 semesters, respectively. Overall, I found that the **Interviewees** were representative of the **Study Samples** to the extent possible.

4.3.1 Reflection Inventory Results for Interviewees

This subsection contains descriptions of the results for the use of reflective learning strategies for all of the **Interviewees**, except for Mark, at the end of the Fall 2020 and Spring 2021 semesters. The reason why Mark's data was omitted was because he did not fill out the EOS for Spring 2021. Results are provided for comparison across the two semesters and different course types.

A few of the same learning strategies were used in all courses, while a larger amount of differentiation existed among the ENGE 1215/1216, science, math, and non-technical courses. There was extensive agreement about the use of reflective strategies associated with the Understanding stage in science and math courses, as well as agreement about different strategies for ENGE 1215/1216 and non-technical courses. Two possible reasons for this dissimilarity could be the participants' perceived usefulness of the course for other courses and their perceptions of the difficulty of a particular course. For example, Micah indicated his judgment about which of his courses was difficult or easy when deciding what to study next:

> "It really depends on what mood I'm in. So sometimes I'll be in a mood where I just need to get stuff done, so I'll just start with the easy stuff and get it out of the way and then I'll leave the harder stuff to be last. And then other moods I'll say, if I get the big thing done, the other thing will be just light and easy and I won't have to worry about them too much."

Overall, the **Interviewees** expressed a greater need to understand course concepts and think about course material in science and math courses during the Spring 2021 semester than in the fall (Understanding stage), slightly less of a need to both think of a better way and re-appraise experience for improvement in performance in math and non-technical courses (Reflection stage), and a greater need to change one's typical way of studying in math courses (Critical Reflection stage).

4.3.1.1 Reflection Employed by ***Interviewees*** *in Fall 2020*

At the end of Fall 2020, the **Interviewees** expressed agreement with statements relating to two or more reflection stages in all of their courses, as shown in Table 4.3 and Tables B.1 through B.4 in Appendix B. The use of multiple reflection stages further illustrates how the **Interviewees** customized their learning strategies among their courses and even among elements within the same course, which addresses my first research sub-question.

Habitual Action and Understanding stages. The **Interviewees** Generally Agreed with the statements about not having to think too much in their ENGE 1215 and non-technical courses

(Habitual Action stage), and Generally Disagreed that they could do the same in their science and math courses. In terms of the Understanding stage, the **Interviewees** Generally Agreed that their science and math courses required them to think about and understand course material, especially course concepts. This result corresponds to what many the **Interviewees** expressed in their interviews about the necessity to understand how to apply course concepts to homework and test problems. In addition, their interview responses revealed self-questioning and self-evaluation of understanding while they were studying, both of which are metacognitive skills applied during the Understanding stage, and may also exhibit the Reflection stage if applied to comparisons to prior knowledge or the recognition of patterns and relationships.

In Table 4.3, the relatively low IQR values for the Understanding stage statements for science and math promote trustworthiness in my decision to associate the median values for Understanding statements with the Likert Generally Agree level. By contrast, the IQR values for ENGE 1215 and non-technical courses were noticeably higher, which indicates a greater difference of opinion about the necessity to continually think in these courses (Krathwohl, 2009b). Both trends also correspond to the results for the Habitual Action statements, as described above.

Even with general agreement about the necessity to think and to understand concepts in science and math courses, Tables B.2 and B.3 contain a few possible contradictions among the **Interviewees**. For example, John and Keith agreed that their math course did not require them to think too much. However, in John's interview responses, he was also thinking about the conceptual side of technical course material anyway, even as he worked problems by rote:

> "So for specifically STEM [sic], I've found so far that just drilling practice problems until all of the formulas

become second nature. And also while doing those practice problems, actively thinking about the theoretical side and how it relates to what I'm doing."

Keith's survey response that he didn't have to think too much in his math course seemed to be incompatible with his desire for conceptual understanding, even though he relied on quiz performance as an external measure of understanding, rather than self-evaluation:

"We have three section quizzes. I feel like those quizzes give me a good idea of how well I understood the material. So, I think usually the homework assignments, just check-in quizzes, those types of tools, help me tell how well I really understood it. Otherwise, if it's just watching the videos, just doing the homework without any feedback, then I can never really be sure about myself."

Reflection and Critical Reflection stages. All of the **Interviewees** Generally Agreed that they often reappraise their experience in order to improve performance in all four of the courses. However, with the exception of ENGE 1215, they were neutral about questioning how others do things and seeking a better way, which also relates to the Reflection stage. This lack of questioning how things are done is also compatible with **Interviewees**' responses to the Critical Reflection statements, with which they were mostly neutral or Generally Disagreed. At the same time, the IQR values for the Critical Reflection statements were largely clustered in the 1.75–2.00 range, which indicates a wider difference in responses than the responses for other reflection stages.

What is also interesting about responses to the last of the Critical Reflection statements is that the **Interviewees** were concerned about improving their performance (Reflection stage), which indicates an approach in the surface to surface-achieving to deep-achieving range, and yet did not change their normal way of studying (Critical Reflection stage). Once again, this relationship triangulates with the learning approaches implied by statements made during interviews, as indicated in Tables 4.1 and 4.2.

Finally, with IQR values of 1.0–2.0 for all of the Reflection Inventory statements relating to non-technical courses, there was less consistency of agreement, disagreement, or neutrality among the **Interviewees**' responses than for other courses. This could be attributed to the variety of non-technical courses considered by this group and was also reflected in several **Interviewees**' statements that they were only studying these courses for the grade in order to improve their GPA.

*4.3.1.2 Reflection Employed by **Interviewees** in Spring 2021*

At the end of the spring semester, the **Interviewees** placed a greater importance on the acquisition of conceptual knowledge in science and math than in their other courses in their responses to the Understanding-related statements in the Reflection Inventory. However, their responses to the Reflection-related statements did not exhibit an increase in importance for science and math, but remained at the same Likert agreement level for all of their courses. This outcome indicates that the **Interviewees** recognized the importance of developing conceptual knowledge as a goal but did not recognize that the methods that they would use to achieve this goal were equally important to their academic and career success. The dissociation of the "product" or goal with the "process" or methods used to reach a goal emerged once again, although in a different form, than those described in Section 4.2.3.

Habitual Action and Understanding stages. **Interviewees** Generally Agreed to a very large extent that the ENGE 1216 course did not require them to think too much (Habitual Action stage), and to a slightly lesser extent for non-technical courses, as shown by the median and IQR values in Appendix B, Tables B.9 and B.12. They Generally Disagreed with the statements about not having to think too much for their science and math courses, but with greater variation, as shown by the median and IQR values in Tables B.10 and B.11. These responses are, once again, similar to the **Interviewees**' descriptions of their learning strategies that involved metacognition, in which they used examples from science and math courses.

For statements in the Understanding stage, **Interviewees** Strongly Agreed with the necessity to understand course concepts in science and math courses, and Generally Agreed for ENGE 1216 and non-technical courses. The IQR values for these statements show very little variation in science and math responses, and only slightly greater variation for ENGE 1216 and non-technical courses. These particular differences can be attributed to the fact that the science and math courses are more likely to have timed tests that require a high level of performance within a short period of time, whereby the **Interviewees** expressed a critical need to understand course concepts for rapid recall and application on these tests.

Reflection and Critical Reflection stages. **Interviewees** Generally Agreed with both statements about finding a better way or trying to improve their performance (Reflection stage) in ENGE 1216 and science courses, but their results were mixed for math and non-technical courses, the latter with an IQR value as high as 1.00 to 1.75. It seems ironic that this group would assert that they would not have to think too much in ENGE 1216, for example, and yet would be thinking about finding a better way to do something and thinking about past experience in order to improve performance. Since ENGE 1216 contains a sizable unit in engineering design, including iterative building and testing, **Interviewees** may have had this process in mind when responding to this question. However, the difference in responses could have been due to the nature of each question, i.e., general vs. specific, which was similar to the differences in certain interview responses to the product-related vs. process-related interview questions.

For the Critical Reflection stage, **Interviewees** largely Neither Agreed nor Disagreed for all four course types regarding challenges to firmly held ideas, even as the **Interviewees** Generally Agreed to re-appraising their experience for their next performance in the Reflection stage. This contrast shows that a change to a different approach or strategy was more strongly influenced by the desire to achieve higher levels of performance than by a curiosity about new knowledge and its effect on existing beliefs, such as comparing new knowledge to prior knowledge. However, changes to one's normal ways of studying were necessary for science and math courses, but not for ENGE 1216 or non-technical courses.

*4.3.1.3 Similarities and Differences in Results Among **Interviewees** Between Fall 2020 and Spring 2021*

Habitual Action and Understanding stages. The **Interviewees**' results for the Habitual Action-related statements yielded the same Likert agreement levels for both the fall and spring semesters for all four types of courses. However, IQR values mainly increased for science and math courses and changed either slightly or not at all for the others. The differences in opinion indicated by increased IQR values shows that some **Interviewees** found their science and/or math material to be more intense in the spring than in the fall, which is to be expected as they encounter additional demands to direct their own learning in order to meet course requirements.

While there was little change in the results for the Understanding statements to thoroughly understand course concepts for ENGE 1216 and Non-technical courses, many

Interviewees Strongly Agreed rather than Generally Agreed that understanding concepts had become even more necessary in the spring-semester science and math courses than in the fall. The IQR values for the medians were also identical, ranging from 0.75 to 1.00.

Reflection and Critical Reflection stages. There were slight changes in responses to the Reflection statements between semesters and among courses. Even though **Interviewees** felt more strongly about understanding course concepts in the spring than in the fall, their quest to find a better way or re-appraise their experience for better performance remained at approximately the same Likert level for both semesters.

Agreement about the Critical Reflection statements regarding challenges to existing beliefs and changing one's way of studying were also more or less consistent between the two semesters, except for a slightly greater tendency to change ways of studying for math courses. At the same time, none of the courses challenged the **Interviewees**' existing beliefs in either semester to a noticeable extent.

The similarities and differences in **Interviewees**' results for both semesters can also be viewed in Figures 4.6 and 4.7 on the next page, as the median Reflection Inventory responses by Kember stage. The columns in each figure were also color-coded by type of course. Each reflection stage was represented by two reflection-related survey questions, labeled in each figure as S1 and S2 for Habitual Action, S3 and S4 for Understanding, S5 and S6 for Reflection, and S7 and S8 for Critical Reflection.

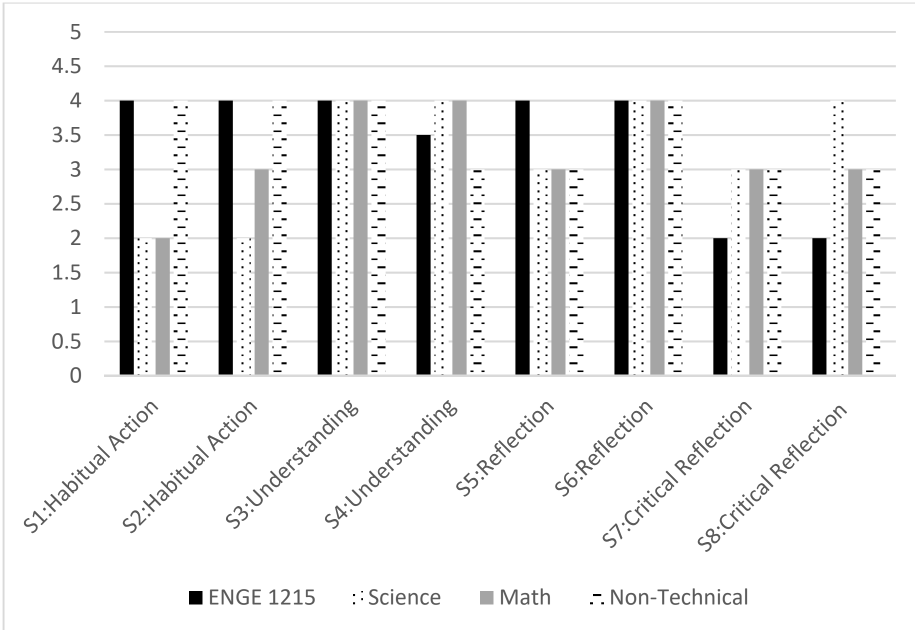

Figure 4.6: Median Reflection Inventory Responses by Kember Stage for Interviewees, Fall 2020

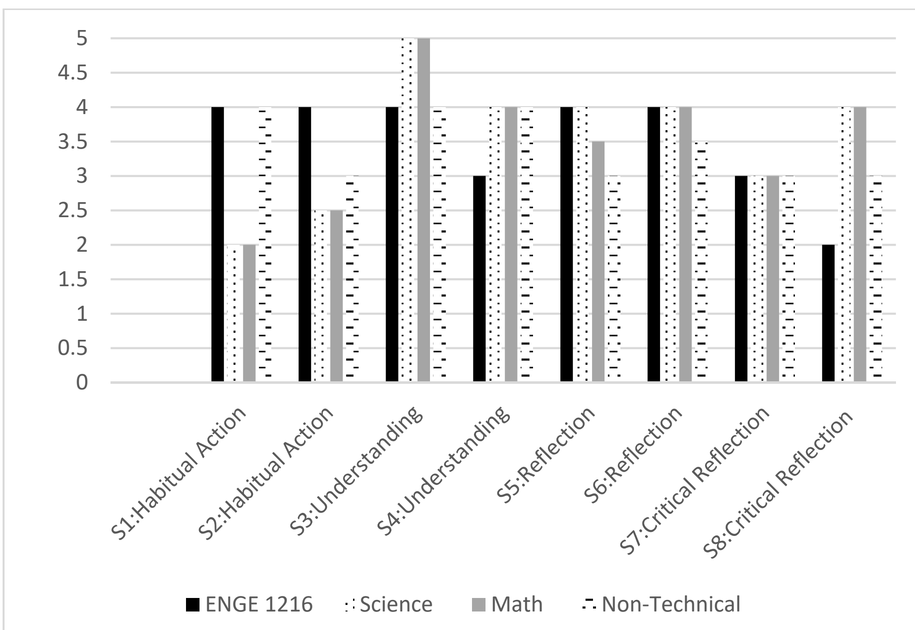

Figure 4.7: Median Reflection Inventory Responses by Kember Stage for Interviewees, Spring 2021

4.3.2 Results for Study Samples

Participants in the **Study Sample** also employed several stages of the Kember reflection model within and among course types, depending on course requirements and how these participants chose to meet them. There were similarities in the use of reflective learning strategies for science and math courses that were different for engineering and non-technical courses, as described in this section. Flexibility in the use of the Kember reflection model is further illustrated in Chapter 6, Conclusions, Section 6.2.1.

4.3.2.1 Reflection Employed by the ***Study Sample, Fall 2020***

Habitual Action and Understanding stages. The approximately 1,200 members of the **Study Sample** Generally Agreed that they did not have to think too much for ENGE 1215 and their non-technical courses (Habitual Action stage), and Generally Disagreed with these statements for science and math courses, as shown in Appendix B, Tables B.5 through B,8. The IQR values for science and math courses showed that the data exhibited a notable amount of spread about the median value, meaning that the Generally Agree and Generally Disagree Likert levels indicated by the medians were not necessarily extensive. This conclusion is also based on the fact that entering engineering students exhibit widely varying amounts of retained technical knowledge throughout their first and second semesters of college (Allen et al., 2008; Kennedy & Upcraft, 2010).

Similar results were found for the necessity to understand course concepts, and to continually think about them (Understanding stage), although the median value for ENGE 1216 indicated neutrality with respect to continual thinking. One notable difference from the Habitual Action statement results was that the **Study Sample** Strongly Agreed about understanding course concepts in both Science and Math, with expected IQR values of 1.0, as shown in Tables B.6 and B.7.

Reflection and Critical Reflection stages. When the **Study Sample** members responded to the statements in the Reflection stage, they Generally Agreed about trying to find a better way to do something in all courses and striving to improve their performance in all courses except non-technical ones, where the IQR of 2.00 (see Table B-8) showed a wider difference of opinion than responses for other courses. This greater disparity of responses is not surprising, given the diversity of non-technical courses pursued.

Responses to the Critical Reflection statements varied considerably between Generally Agree and Neither Agree nor Disagree for all courses and between statements for the same course, given seven of eight IQR values of 2.00. Once again, these differences can be attributed to the diversity of courses that the **Study Sample** members would consider to be non-technical.

4.3.2.2 Reflection Employed in Spring 2021

There was a greater agreement about the use of Reflection-related statements containing the metacognitive strategies of thinking about a better way and learning from experience after the spring semester across all courses. While it may seem to be contradictory to use metacognition in a course where a student feels that they do not have to think much, the Kember reflection stages are not mutually exclusive to courses, and their use can also vary with context within a course.

Habitual Action and Understanding stages. The **Study Sample** members Generally Agreed that ENGE 1216 and non-technical courses did not require them to think too much (Habitual Action stage), and Generally Disagreed for their science and math courses, although there was a wider difference of opinion for math courses than for the others, as shown by the IQR value of 3.00 in Table B.15. This difference could be attributed to the differences in retained math knowledge among the members, which was expressed by Mark in his interview as how much of his current math course was familiar to him, based on his math courses at the secondary level.

The **Study Sample** Strongly Agreed or Generally Agreed that it was important to understand course concepts (Understanding stage) in all courses, but especially in science and math, where the spread about the median values were lower than for ENGE 1216 and non-technical courses. However, when asked about their agreement with the statement regarding the necessity to continually think about the course material, the **Study Sample** Generally Agreed for science and math and were neutral about ENGE 1216 and non-technical courses.

Reflection and Critical Reflection stages. Reflection was more extensively practiced during the spring semester by the members of the **Study Sample** in all four types of courses, as they Generally Agreed with both statements related to the Reflection stage: thinking of a better way to do something, and re-appraising experience for the next performance. In addition, IQR values equaled 1.00 in all cases, indicating an expected amount of spread about the median for this sample size.

Results for the Critical Reflection statements were mixed, as none of the courses caused the **Study Sample**'s response median value indicate Neither Agree or Disagree on the Likert scale, and yet the **Study Sample** members tended to change their normal way of studying in science and math, most likely in response to course demands and/or poor test grades. This last conclusion was expressed by John in his interview, when, based on his test grade in a major-related course, he needed to change his way of preparing for tests from just plugging in formulas to being able to integrate several course concepts into a test problem.

*4.3.2.3 Similarities and Differences in **Study Sample** Results Between Fall 2020 and Spring 2021*

Study Sample results were nearly identical for statements relating to all of the reflection stages, for both semesters and for all of the course types, as seen by comparing the **Study Sample** columns in Tables 4.3 and 4.4. Only the IQR values differed between fall and spring and for only seven of the 28 statements listed in these tables. This outcome is notable in view of the fact that the **Interviewees**' results were not nearly as similar. One way to explain this difference between the two groups is the fact that the **Interviewees** were interviewed about their learning strategies, which may have caused them to think more carefully about the strategies mentioned in the reflection statements than they might have otherwise.

The similarities and differences in **Study Sample** results for either semester are depicted graphically in Figures 4.8 and 4.9 on the next page. Once again, each reflection stage was represented by two reflection-related survey questions, labeled in each figure as S1 and S2 for Habitual Action, S3 and S4 for Understanding, S5 and S6 for Reflection, and S7 and S8 for Critical Reflection.

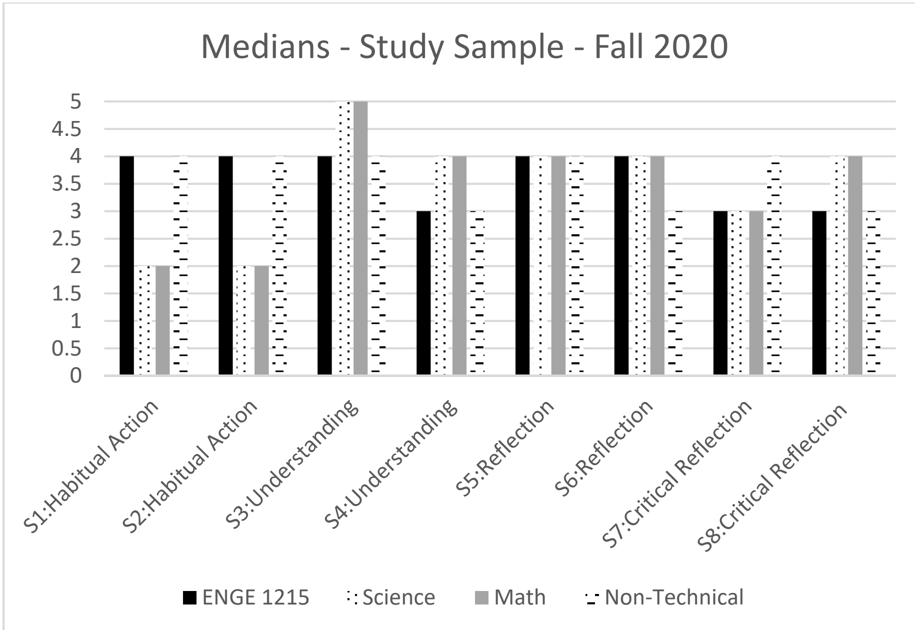

Figure 4.8: Median Reflection Inventory Responses by Kember Stage for Study Sample, Fall 2020

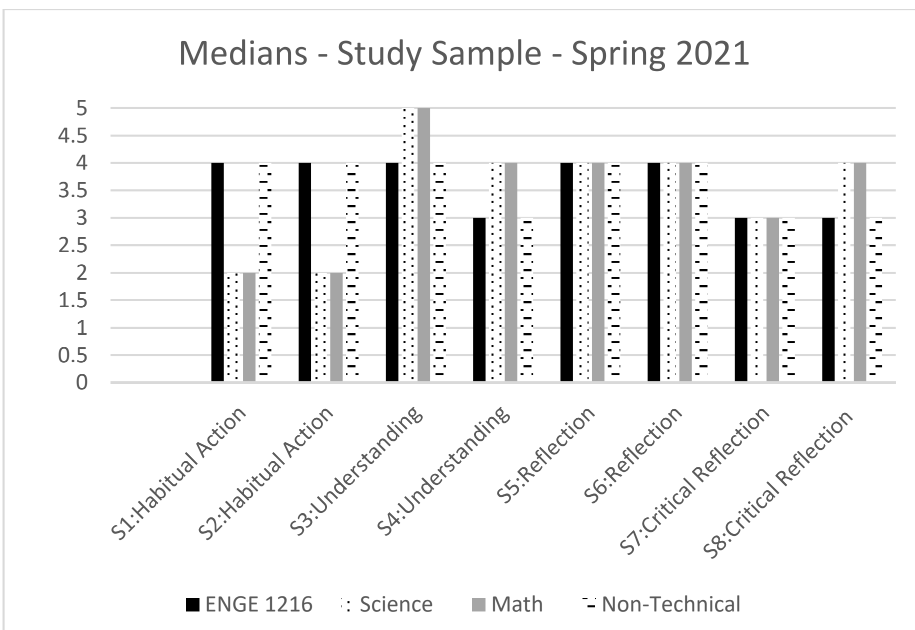

Figure 4.9: Median Reflection Inventory Responses by Kember Stage for Study Sample, Spring 2021

These figures show the percentages of **Study Sample** members who responded according to each Likert agreement level. The columns in each figure were also color-coded by type of course.

4.3.3 Comparison between Interviewees and Study Sample

A similar analysis, described above, was performed for the **Study Sample** quantitative data. Many of the results were similar to those for the **Interviewees**, indicating, once again, that the **Interviewees** were representative of the **Study Sample**s to the extent possible. These similarities are also shown in Tables 4.3 and 4.4 in the introduction to Section 4.3.

4.3.3.1 Similarities and Differences During Fall 2020

Habitual Action and Understanding stages. Results for the Reflection Inventory statements about not having to think too much (Habitual Action stage) were essentially the same for the **Study Sample** as for the **Interviewees**, for all courses; i.e., Generally Agree for ENGE 1215 and non-technical courses, and Generally Disagree for science and math courses. Conversely, both groups Generally Agreed about thinking about what they were being taught in all courses, and the **Study Sample** more Strongly than Generally agreed about understanding concepts in science and math courses (Understanding stage).

Reflection and Critical Reflection stages. **Interviewees** were more skeptical about finding a better way to do something (Reflection stage) than the **Study Sample** in science and math courses than in engineering and non-technical courses but were more amenable to re-appraising their experience for better performance, which is also indicative of the Reflection stage.

Neither the **Interviewees** nor the **Study Sample** experienced a challenge to their firmly held ideas in engineering, science or math, but the **Study Sample** Generally Agreed to a challenge to beliefs in their non-technical courses (Critical Reflection stage). The reason for this difference is not entirely clear but could be based on how a participant interpreted the term, "firmly held ideas." These "ideas" or beliefs could range from a long-standing impression that was challenged by a course prompt, or it could be new course information hitherto unknown by the participant.

Both groups Generally Agreed to changes in their ways of studying for science and math, but not in ENGE 1215 or Non-Technical courses. Apparently, since academic performance, i.e., test grades, influences learning strategies, it is not at all surprising that participants would change their learning strategies in order to attain higher grades in these two types of courses.

4.3.3.2 Similarities and Differences During Spring 2021

Habitual Action and Understanding stages. Both the **Interviewees** and the **Study Sample** produced the same results for the Habitual Action statements about not having to think too much in their courses, i.e., Generally Agreed with the statements for ENGE 1216 and non-technical courses, and Generally Disagreed for science and math courses. Both groups also Generally Agreed about the necessity to understand course concepts in ENGE 1216 and non-technical courses, and Strongly Agreed for science and math courses (Understanding stage).

Reflection and Critical Reflection stage. The **Interviewees** and the **Study Sample** also Generally Agreed about trying to think of a better way and re-appraising their experience for next performance in ENGE 1216 and science but were in less agreement for math and non-technical courses (Reflection stage). Finally, and once again, neither group agreed that any of these courses had challenged their firmly-held beliefs, although both groups Generally Agreed that they needed to change their ways of studying in science and math (Critical Reflection stage).

4.4 Summary

I demonstrated several ways to promote the trustworthiness of the study results by showing how the **Interviewees**' data was representative of the data from the **Study Samples** and by triangulating the **Interviewees'** survey results with their interview data. The extent of representation was illustrated in Figures 4.4 and 4.5 for the survey's purpose of studying responses, and in Figures 4.6 through 4.9 for the use of reflective learning strategies identified in the Kember reflection model. Triangulation was manifested in, for example, the self-regulating reflective learning strategies of self-questioning and self-evaluation that were described by the **Interviewees**, where these strategies also appeared in their reflection-related survey responses. Additional relationships emerged between interview data and survey responses, such as the quest for high grades as the primary purpose of studying.

Several patterns emerged from this summary of the semi-structured interview data and reflection-related survey data collected from the **Interviewees** during the Spring 2021 semester. The interview results were based on 262 responses from coded transcripts. The use of reflective learning strategies by both **Interviewees** and two **Study Samples** of first-year engineering students was also explored through Likert scale results from eight reflection-related questions in the ENGE 1215 and ENGE 1216 end of semester surveys.

The most notable difference between the fall and spring semesters for the **Interviewees** was that they were more focused on attaining high grades as their purpose for studying in the spring than in the fall. The results also revealed that many **Interviewees** stated that their overall purpose for studying was to achieve high grades by preparing for tests, through a surface-achieving and less frequently a deep-achieving approach, and yet many of their learning strategies reflected a deeper engagement with learning than expected from students whose primary focus was on grades rather than on learning. This means that, even when the **Interviewees** were engaged with learning, their reason for doing so had more to do with grades than with the act of learning itself.

In addition, the **Interviewees'** reflection-related survey results illustrated a greater emphasis on understanding course concepts and changing their methods for studying in Science and Math courses in the spring than in the fall, but little change in the use of any of the reflective learning strategies in the ENGE or non-technical courses. At the same time, **Interviewees** placed a heavy emphasis on understanding course concepts in all four types of courses during both semesters. The use of multiple reflection stages further illustrated how the **Interviewees** customized their learning strategies among their courses, and even among elements within the same course, which further addresses my research question and sub-questions.

Responses to the product-related interview questions indicated a deep approach when the **Interviewees**' purpose for studying was mastery of course material, as opposed to a surface-achieving or deep-achieving approach when their purpose was performance-based. This dichotomy illustrates how these students customized their learning approaches and strategies among their courses, rather than following the same approaches and strategies for all courses.

A comparison of **Study Sample** results for the purpose of studying from Fall 2020 to Spring 2021 revealed that there was a wider variety of purposes for studying in the fall semester, as shown in Figures 4.4 and 4.5. Figure 4.5 also shows that the purpose of studying in order to attain a high grade was much more prevalent in the spring semester than in the fall, which accounts for lower numbers of other reasons or combinations of reasons. The most common combinations of reasons were to pass the course and get an A, and to prepare for future success and get an A.

Survey results also showed comparatively little change in the use of reflective learning strategies between the fall and spring semesters for the **Study Samples**, except for non-technical courses, whose median values for strategies associated with the Reflection and Critical Reflection stages were different between the semesters, as shown in Figures 4.8 and 4.9. This variation could be attributed to the greater variety of non-technical course requirements taken by the **Study Sample** participants during either semester, whereas their technical courses were likely to be more homogeneous. Figures 4.8 and 4.9 also show the uniformity of agreement among different types of courses for learning strategies associated with the Understanding and Reflection stages.

Several underlying themes and issues will be addressed and explored in the next chapter. These include more detailed answers to my research question and sub-questions, and the overall alignment of my study. Additional issues include the absence of the surface-learning approach in favor of the surface-achieving approach, the dichotomy between extrinsic goals and intrinsic engagement with knowledge, and the relationships between reflection and metacognition. Finally, the importance of self-regulating learning strategies to academic success emerges as a set of highly useful and meaningful methods for learning course material. These strategies primarily consist of self-questioning, self-monitoring, and self-evaluation, although self-testing can also be useful under certain circumstances.

5.0 Discussion

5.1 Introduction

This chapter contains the answers to my research question and sub-questions and a description of the alignment among the overarching problem, research question and sub-questions, conceptual framework, research methods, and results. Section 5.1 provides additional insights into the reasons why the **Interviewees** used different learning strategies among their courses, and the ways in which reflective strategies, in particular, were helpful. In addition, several issues arising from the results are explored further in Section 5.2, such as the absence of the surface learning approach among the **Interviewees**, mastery vs. performance goals, and the relationships among reflection, metacognition, and certain self-regulating learning strategies.

One possible reason for why the **Interviewees** did not follow the surface approach includes the influence of standardized testing throughout their educational career, as well as the timed tests that were common in their college courses. Both of these assessment methods encouraged a surface-achieving or deep-achieving approach. In addition, the formation of a "science identity" within a community of like-minded students may cause students to concentrate on test performance and grades in order to belong to such a community (Aschbacher, LI & Roth, 2010). While the surface-achieving approach may lead to high grades, students may choose to follow a deep-achieving approach if, in their quest for a high grade, they realize that a deep engagement with course material may be necessary to understand concepts, or a deep engagement arises from their interest in the subject matter.

Reflection aids metacognition through the use of self-questioning and self-evaluating learning strategies, in particular, and examples of this effect are described in Section 5.2.5. Additional quotations from interview transcripts are also included in both Sections 5.1 and 5.2 to provide further evidence for the answers to the research question and sub-questions, as well as to address the emergent issues.

5.2 Answering the Research Question

The overarching research question is as follows:

- How do first-year engineering students describe their learning approaches and strategies?

The sub-questions whose answers support this research question are the following:

- How do first-year engineering students customize their learning strategies among their courses?
- How do first-year engineering students employ reflection as part of their learning strategies?

The answers to these two sub-questions involve learning strategies which are responsive or reflective. As stated in Section 1.1, responsive strategies are applied with a specific end goal in mind, such as understanding a concept or solving prospective test problems. Reflective strategies prompt for additional exploration into course material in order to discover and use the deeper meaning that is there but that is not always obvious.

5.2.1 Answering the Research Sub-Questions

The following sections contain insights into the study results as to how and why the **Interviewees** customized their learning strategies among their courses, and their choices of reflective learning strategies to refine and enhance their learning. Major differences leading to customization included strategies for problem solving based on the attainment of desired levels of conceptual knowledge in technical courses, and memorization of facts and definitions focused almost entirely on test performance in non-technical courses. It also appeared as though there were relatively few strategies that **Interviewees** would apply to both types of courses and fewer instances in which they recognized that they were using reflection, even though many of the specific strategies they described are direct applications of reflection.

5.2.1.1 The First Sub-Question: How Students Customized Learning Approaches and Strategies Among Courses

I did not find it surprising that the **Interviewees** in this study selected their learning approaches and strategies according to the requirements of each of their courses, and in concert with their own learning needs, constraints, and resources. This is part of what students do, which may not align with what their instructors want them to do (Biggs, 1999; Biggs & Tang, 2011; McKeachie & Svinicki, 2013; J. A. Moon, 2004). For example, learning strategies for technical courses were commonly focused on problem solving and the attainment of conceptual knowledge in order to meet course requirements, while non-technical courses prompted for memorization, note taking, and an occasional recognition that patterns and relationships existed among items of knowledge. Interest in the course material was also a major factor in an **Interviewee's** willingness to engage with it and explore it beyond the course requirements, where interest has been shown to motivate a desire for a deeper engagement with learning (Jones, 2009, 2018).

It was clear that the **Interviewees** with an overall surface-achieving or deep-achieving approach to their learning were more engaged with the material in their technical courses than in their non-technical ones, as shown by their use of the self-questioning, self-teaching, and self-evaluation strategies in those technical courses. Conversely, **Interviewees** with an overall deep learning approach tended to view their education more holistically and were more likely to recognize that both technical and non-technical courses added value to their post-secondary education. Here is an example from Michael, a deep-approach **Interviewee,** who balanced his workload and learning approaches to exhibit a more holistic approach to higher education:

"Like, yeah, I'll devote time to do math work today or something, right? But then also be sitting around and just reading an article about something and kind of go down a 20-minute session of just looking at different articles and reading about stuff just because it's somewhat related but somewhat not. Like I'm into stocks and stuff, so I'll read about technology stocks that also apply to my major. I'm doing computer engineering, so I'll read about stuff that involves machine learning, but also in an economical sense."

5.2.1.2 The Second Sub-Question: How Students Use Reflective Learning Strategies and Their Relationship to Learning Approaches

This subsection contains the results of the **Interviewees'** reflection-related survey results triangulated with their interview data, and examples of the self-regulating, metacognitive role of **Interviewees**' reflective learning strategies. These results were compared to those for both **Study Samples** to reveal similarities and differences, which illustrate the variations in the selection of surface-related and deep-related learning approaches, depending on context, constraints, and requirements to be met.

Reflection-related survey questions results for **Interviewees** varied little between the fall and spring semesters, with general agreement that Habitual Action strategies might be useful for ENGE and non-technical courses but not for science or math courses, where understanding concepts and thinking about the course material, indicative of the Understanding stage, were paramount, especially in the spring semester (see Tables B.14 and B.15). The Understanding stage may also be considered to consist of comprehension in isolation, such as understanding a concept without relating it to alternative contexts, such as real-world situations, and relying on a textbook or another external source of knowledge (Kember et al., 2000, 2008).

However, the reflection-related strategies of questioning methods and finding a better way, and re-appraising past performance to improve future performance, were recognized as important for all of the courses included in the reflection-related survey questions for both semesters and by many **Interviewees**. While the Interviewees could, indeed, question their own methods for acting, they could also question the methods of others whom they observe, particularly other students who appear to be successful in attaining high grades and exhibiting an interest in learning. This would mean that reflection is not only focused on the individual but may also be influenced by social interactions (Finlayson, 2015). The actions described by the reflection-related survey questions linked to the Reflection stage also imply the need for careful consideration before acting and a questioning of past practices, such as learning strategies, in the light of new evidence (Kember et al., 2000).

By contrast, the strategies in the Critical Reflection stages were rarely followed by either the **Interviewees** or the **Study Samples**, especially the statement that a particular course had "challenged firmly held ideas." If the college experience is meant to help a student refine and expand their critical thinking capabilities by offering alternative points of view that would cause them to question their ideas and habits, that did not seem to be happening here.

The **Study Samples** in Fall 2020 and Spring 2021 agreed with the **Interviewees** about the relative use of reflective strategies among all of the stages of the Kember reflection model, even with Strong Agreement, not just General Agreement, about the necessity to understand course concepts in Science and Math courses, as taught by the instructor. It was as if both groups treated the lecturer as the source of the "correct" answers and interpretation of concepts, although it could also be argued that this is also a way to correct or avoid forming misconceptions (King & Kitchener, 1994; Streveler et al., 2015). As an example, here is how Nathan described his approach to difficult course material:

> "So the first thing I'll either go to a friend that I know, and that I think might understand, too, and ask them if they can help, but most of the time I'll just go to the teacher, like during office hours, or just ask a question during class. Obviously, they're experts, so they're the best person to ask."

Nathan's reflection-related survey questions results revealed that he was not particularly interested in questioning the methods of others and thinking of a better way, in either semester (Reflection stage) although he was very interested in re-appraising his past performance for improvement on the next graded assignment or test (also in the Reflection stage). From Table 4.8, Nathan's responses were labeled with the surface-achieving approach much more often than with other approaches.

It could be argued that technical problem solving requires the recognition of patterns and relationships among items of knowledge, which is a reflective learning strategy, as shown in Table 3.4. Michelle did this in two ways: using Google Images for recall of past topics and their relationships to what she was currently studying and attempting to integrate all of the topics in a course into a continuum through common elements and relationships.

In general, the **Interviewees** did not explicitly use the terms “patterns” or “relationships” with respect to their technical courses, and only used them occasionally with their non-technical courses, as in this excerpt from John:

> “It’s like remembering facts and recognizing kind of historical patterns, patterns throughout. I think that’s especially true in history classes. What’s true for one era of history is pretty much true for another era, you detect it.”

John’s overall learning approach was closer to deep-achieving than to either deep or surface-achieving, according to Table 4.8, based on his responses to both product- and process-related interview questions. He also responded to the reflection-related survey questions statements about trying to think of a better way to do something with Neither or Generally Disagree, yet Generally Agreed that he often re-appraised his experience for future performance improvement. When combined with his interview responses, it became even more evident that John tends to follow a deep-achieving, rather than deep, learning approach.

Michelle, John, and Kira limited their search for patterns and relationships to a single course in an attempt to better understand how all of the course topics fit together as a form of synthesis within the course (Krathwohl, D.R., 2002). However, a more valuable use of this reflective learning strategy is to find patterns and relationships among topics in different courses, thereby developing an ability to adapt concepts to alternative contexts and thereby enlarging one’s intellect (Heywood, 2014).

Kira appeared to use the search for patterns and relationships strategy when trying to understand course concepts in the following way:

"And I think also, my mind works really well when I could get a systemic understanding of the concept. Like, 'Oh, this part works with this part and they match up,' and things like that. Once I just walk in, then I try to use that method to [gain] understanding."

Kira's reflection-related survey questions results were inconclusive, as she Generally Agreed or Neither Agreed nor Disagreed with all of the statements for all types of courses. It is possible that she was exercising a type of response bias based on end-of-semester fatigue and a temporary lack of willingness to think before responding to the reflection-related survey questions statements.

Despite their low indications of practicing reflection, **Interviewees** gave multiple examples of reflective strategies, once again not identifying them as such but using them nevertheless. Michael reflected on objects in his environment and looked for ways to relate them to course concepts. Pete and Mark compared new knowledge to prior knowledge as part of judging their comfort level with learning something that was unfamiliar. Larry also used this comparison method to conclude that knowledge is often cumulative, as new concepts are not only related to, but are built on, ones that he learned earlier. These examples illustrate the fact that reflective learning strategies were being used by these first-year students, even if these strategies were not recognized as reflective, and did not explicitly appear in the reflection-related survey questions or in the original Kember reflection questionnaire.

5.3 Additional Issues Arising from this Study

This section contains the exploration of several of the study results for greater understanding and insight, using comparisons to prior studies and in consideration of the influence of context on the study results. First, the absence of the surface learning approach among the **Interviewees** could be attributed to the influence of standardized testing and/or the formation of a specific identity and community of practice. Next, the ramifications of a mastery vs. performance mindset is analyzed in terms of engineering students' sense of competence with respect to technical course work. The dichotomy between extrinsic goals and intrinsic engagement with knowledge is also explored, in view of the perception that these two aspects of learning seem to be mutually exclusive and the fact that they actually coexisted among the learning approaches of many of the **Interviewees.**

The last two topics in this section deal with the relationship between reflection and metacognition through the exercise of self-regulating learning strategies, such as self-questioning and self-evaluation. A large amount of evidence for the use of self-regulating learning strategies emerged from the coded results, and further analysis of these results revealed how reflection facilitates metacognition through the mechanisms of self-regulated learning.

5.3.1 Why is the Surface Approach Largely Missing from the Results?

The absence of the surface learning approach is evident from Figures 4.2 and 4.3, whether alone or in combination with other approaches. There are two possible reasons for this absence. One is that over 95% of the Interviewee and **Study Sample** participants reported that they had participated in Advanced Placement or International Baccalaureate programs prior to attending college. These programs provide greater academic intensity than their mainstream counterparts, and my participants' overall academic success was measured by standardized testing during the senior year (International Baccalaureate Organization, 2021; The College Board, 2021). No matter how much or how little these participants had actually learned in these programs, they were rewarded only by the attainment of high test grades, which may have granted them the International Baccalaureate diploma and/or the opportunity to be granted college-level course credit. This caused them to be achievement-oriented, which is not an attribute of the surface learning approach but is indicative of the surface-achieving or deep-achieving approach. It was also recognized in the literature that students who participate in these programs often associate learning with the attainment of grades, especially test grades (Sacks, 1997; Walberg, Stone & Phelps, 2017).

Expectations for accountability at the secondary school level may also influence the development of a surface-achieving approach to learning in place of what might have been a surface approach (Barksdale-Ladd & Thomas, 2000; Gietz & McIntosh, 2014). When faced with the pressure to produce a profile that contains high standardized test scores for the institution, educators may "teach to the test," which further emphasizes the importance of the test, rather than student learning, being what is measured and rewarded (Barksdale-Ladd & Thomas, 2000; Biggs, 1988; Gietz & McIntosh, 2014; Haldyna, Haas & Allison, 1998; Sacks, 1997; Walberg et al., 2017). Therefore, it is not surprising that, while students may seek shortcuts to studying, which could be considered as part of the surface approach, they do so with the intent to attain high grades, which is part of the surface-achieving approach, because they have been conditioned to do so (Zwick & Green, 2007).

A second possible reason for the absence of the surface approach among the study participants is the formation of a "science identity" by students who pursue technical fields, who then become "high-achieving persisters" with the encouragement of their families and through social interaction with like-minded students, both inside and outside the classroom, in a competitive community (Aschbacher, et al., 2010). Nine of the fifteen **Interviewees** in my study measured their success by the attainment of high grades, which gave them both personal satisfaction and identification with other high-achieving engineering students, with whom they participated in a "community of practice," as described in the literature (Aschbacher et al., 2010).

Another possible reason that the Interviewees seldom indicated that they used a surface approach to learning is because they responded to the interview questions by mentioning the learning strategies that they used most often. What they did not articulate, but might have also been true, were the ways in which they processed new information, such as reading material for the first time just to become acquainted with how it is written, and then reading it again for understanding (Biggs, 1988; Marton, 1975). The initial reading might be considered to be a surface approach, explained in the literature as focusing on the surface of the text, to be followed, or not, by deeper exploration of the content (Biggs, 1988; Marton, 1975). Therefore, the surface approach can be useful with respect to initial familiarization, but it was the exclusive reliance on the surface approach to the exclusion of the deep approach that Biggs decried, and which later led to his framework for constructive alignment by instructors in order to encourage more students to adopt a deep approach to their learning ((Biggs, 1988, 1996; Biggs & Tang, 2011).

In Section 3.6.1, I mentioned the reported correlation between Biggs' surface learning approach and Kember's Habitual Action reflection stage, and how my results might confirm or refute it (Kember et al., 2000, 2008; Leung & Kember, 2003). Some of my results did refute this correlation by showing how the Interviewees sometimes used more than one stage of the reflection model for a certain type of course, such as the combination of Habitual Action and Reflection stages in their engineering courses. Since Kember had also correlated the deep learning approach with the Reflection stage, the original correlation may be questioned when learning approaches and reflection stages are considered with respect to technical vs. non-technical courses.

5.3.2 Pursuing Goals for Mastery or Performance, and the Role of Competence

The difference between a mastery and a performance orientation is described in Section 4.2.1, using goal orientation theory, where mastery was identified as internally driven and performance as externally driven (Pintrich, 2000). In Section 4.2.1.1, my study results revealed that nine out of fifteen **Interviewees** expressed their purpose for studying with a focus on their performance on graded course work, while six **Interviewees** favored mastery of course material in order to gain some level of conceptual knowledge, especially in their technical courses.

In either case, the **Interviewees** were fulfilling a need for confirmation of their own competence, as described in Section 2.2.1, according to self-determination theory (Deci & Ryan, 2000). Confirmation of competence was easily recognized through high grades, while confirmation of competence through mastery emerged largely from the ability to teach other students seeking help in ways that they could easily understand. In addition, these confirmations of competence also support academic self-concept, which is based on how a student feels about their own competence (Bong & Skaalvik, 2003).

Another important aspect of academic self-concept is the ways in which students perceive how they are viewed by other students in social interactions both inside and outside the classroom (Bong & Skaalvik, 2003). It is notable that it is not the way in which others view them, but the way in which students perceive how other students view them that matters (Bong & Skaalvik, 2003). This social influence also relates to the "science identity" adopted by students in technical fields, as described in Section 5.2.1 (Aschbacher et al., 2010; Bong & Skaalvik, 2003). For example, first-year engineering students often form a "community of practice," which facilitates a “science identity” (Aschbacher et al., 2010). These communities may arise from interactions with like-minded students in technical courses that they take in common, through study groups (as used judiciously by **Interviewees**), and through living-learning communities, in which certain **Interviewees** participated.

Interviewees with a mastery mindset, and **Study Sample** members whom they represent, also believed that, once they understood technical course concepts to the extent that they could solve unfamiliar or highly complex homework or test problems, they could be equally successful in future courses. This belief is a manifestation of self-efficacy for future success (Bandura, 1977; Bong & Skaalvik, 2003). Self-efficacy reinforces competence and it may also mitigate academic disengagement when future courses, whether technical or non-technical, become more complex, more difficult, and/or less well-defined than first-year courses.

Conversely, **Interviewees** and **Study Sample** participants with a performance mindset were much more concerned about their short-term success, such as succeeding on the next test. Both types of students exhibit a motivation to learn, which is a basic human need (Deci & Ryan, 2000). However, those with a performance mindset were not concerned about their probability of success beyond their current course load, and this lack of consideration for the academic challenges of upper level engineering courses, in particular, may lead to their disappointment that the support that they received during their first year is no longer present, as stated earlier (Kennedy & Upcraft, 2010; Schreiner, 2010; Schreiner et al., 2012).

The major difference between the mastery and performance orientations appears to be the urgency versus the importance of meeting a goal for learning. Urgency arises from the perceived necessity to attain a high grade on the next graded course work, which is an extrinsic goal; while importance is assigned to the desire for a deep engagement with knowledge for retention and transfer, which is an intrinsic goal. It is the intrinsically motivated, deeply engaged student that has been shown to be more successful in their later college years, due to strong prior preparation during their first year (Downing, 2009; Geisinger & Raman, 2013; Litzinger et al., 2011; Prince & Felder, 2006; Seymour & Hewitt, 1997).

Greater understanding about choices between the mastery and performance orientations for setting goals, as well as the influence of motivation on academic engagement, could be explored beyond what I have shown in Sections 2.2 and 2.3. Possible areas for study could also be built upon earlier investigations into the influence of motivation on learning approaches and strategies using additional aspects of the MUSIC model, the self-efficacy and self-determination theories, the authentic experiences of second-year students, and the influence of competition for high grades and their influence on students' prospects for engineering employment (Deci & Ryan, 2000; Gardner et al., 2010; Gore & Hunter, 2010; Jones, 2018). Possible research questions could include the following:

- How does motivation influence judgments about the value of certain learning strategies?
- How does goal setting relate to choices among learning approaches?
- In what contexts could the surface approach to learning be appropriate?

5.3.3 The Dichotomy Between Extrinsic Goals and Intrinsic Engagement with Knowledge

Based on the results from Table 4.9, in which only four of the **Interviewees** exhibited a consistent learning approach for both product-related responses, such as what to accomplish (goals) and process-related responses as the means to accomplish their goals, the contexts for these responses were a major influence on the choice between a surface or surface-achieving approach and a deep or deep-achieving approach to either type of interview question. As indicated in Section 4.2.3, engagement with learning seemed to emerge from the quest for high grades rather than through the desire to gain additional knowledge.

Engineering educators may wonder, given the intended academic intensity of college-level technical and non-technical courses, and the levels of effort that many students exert in them, why these students set goals for themselves for grades rather than goals for learning. My results contained examples of how most of the **Interviewees** advanced their learning through meaningful engagement with course material, as indicated in Section 5.2.2.2, even when their stated purpose for studying was to achieve high grades in their courses.

Learning strategies are actually behaviors that may become habits if practiced frequently, but they can also foster a mindset that certain strategies are suitable for all situations. When a student reflects about learning strategies that may have helped them with understanding and/or success in the past, they may decide to continue studying according to these strategies. This works as long as the study context, such as course requirements, remain the same for apparently similar courses. One example of how this mindset was counterproductive was described by John in his interview excerpt in Section 4.2.1.1. John thought that his familiar strategies for problem solving would not suffice in a more technically complex course.

When a student decides to pursue the attainment of high grades, they select strategies that they believe will help them achieve that goal, i.e, strategies that they believe to be useful (Perugini & Conner, 2000; Richetin, Perugini, Adjali & Hurling et al., 2008). However, the student is not guaranteed a high grade just for applying a particular strategy, due to factors in grading that they do not control, such as subjective grading by instructors, their state of mind or level of motivation while completing the graded instrument, and their performance with respect to other students in their class through grade curving.

In this study, a large number of the **Interviewees** who exhibited engagement with learning applied their learning strategies according to the deep-achieving approach in order to increase their perceived probability of success through factors that they could control. In addition, factors affecting their outlook toward the goal of attaining high grades could also influence their choices of learning strategies and the intensity with which they pursue them, such as their desire for the goal, the perceived feasibility of attaining it, and any anticipated emotions toward succeeding or failing (Perugini & Conner, 2000).

The predominance of the surface-achieving and deep-achieving approaches over the surface and deep approaches in my study results indicated the importance that the Interviewees placed on achieving high grades on timed assessments, i.e, tests, as well as for other forms of formative and summative assessment. Testing can be a useful way to reinforce technical concepts or the sequencing of facts and relationships in the humanities, and self-testing has been named by study participants as more helpful to their learning than just reading, especially when they wanted to evaluate their understanding of course information (see Table 2.2 in Section 2.3.3.3) (Hartwig & Dunlosky, 2012; Kornell & Bjork, 2007; Kornell & Son, 2009; Morehead et al., 2016).

Our department's introductory engineering courses contain units in technical skill development for engineering graphics and computer programming, in addition to teamwork, technical communication and problem solving. The combination of technical and professional skills in these courses provides more of a "liberal education" for our students than other technical courses are able to provide, and might also explain why my reflection-related study results revealed similarities between engineering and non-technical courses.

The graphics and programming units were often assessed through timed tests in the past, until these tests were discontinued in favor of more realistic assessments in keeping with course learning objectives. In addition, it could be argued that timed tests in engineering courses did not measure student learning realistically, due to variations in both student learning styles and responses to high pressure situations that required instant recall. Our engineering instructors could implement guided practice in self-testing, where students complete a test under timed conditions, but their results are graded on participation in not only taking the test, but in correcting their mistakes and explaining how these mistakes were made. Reflection can also be used when students discover better ways to solve these test problems, whether different methods are supplied by the instructor or by other students.

5.3.4 Relationships Between Reflection and Metacognition

The examples in this section illustrate the mental processing or metacognitive role of reflection in learning as a careful examination of knowledge and beliefs in the face of available evidence (see Section 2.4.1) (Leung & Kember, 2003). When applied to problem solving in technical courses, reflection is helpful when the solution is not obvious (J. Moon, 2004, 2007). The **Interviewees** often mentioned problem solving as a useful method of learning technical course material, especially when preparing for tests by working practice tests and additional practice problems provided by instructors or available online. Similarly, difficult course material also required additional practice, according to both Micah and Pete, from which patterns and relationships among facts and concepts could emerge, as described by Larry:

"I use this approach for both difficult material and very vast material: for example, if I'm studying for a final or something like that, where I have all of these different concepts I need to memorize, I try to break it down. I also try to look for patterns in each of these things, because that's the way I kind of learn is I like to find how things work. Once I know that, it's easier to understand the concepts behind them and stuff."

In the reflection-related survey questions, Larry's results were similar to the median values for all of the **Interviewees** with respect to the strategies in the Reflection stage, especially with respect to improving performance, and his overall learning approach was deep-achieving rather than deep (see Tables 4.8 and 4.9); but his abovementioned interview excerpt indicated that he was willing to explore knowledge more deeply than either of the achieving-based approaches would indicate. This is another example of engagement with knowledge that contradicted Larry's stated purpose for studying in his interview. This dichotomy was introduced in Section 4.2.3 and is further explored in Section 5.3.1.

Even though the **Interviewees** did not report changes to their "firmly held ideas" or beliefs in any of the four courses in the reflection-related survey questions' Critical Reflection stage, there was General Agreement about the other Critical Reflection statement about changing one's ways of studying, at least in the Science and Math courses. Sometimes this change becomes necessary as a result of a "wake-up call" from a poor test grade, as John related from his interview in Section 4.3.1.1.

Even though Biggs did not seem to mention reflection in relation to metacognition or to his term, "metalearning", he did link the self-questioning learning strategy as an important distinction between the surface and deep learning approaches (Biggs, 1988, 1999). Self-questioning also involves a search for evidence, which is an indication of the use of reflection in not only metacognition, but in the acceptance of uncertainty and the variation of knowledge under multiple contexts. The reflective aspects of self-questioning were evident in these responses by **Interviewees** when asked about the kinds of self-questions they ask while studying, where the evidence is a perception of understanding, and therefore competence:

Valerie: "Do I really understand what I'm doing, or am I just…Did I just memorize this certain problem?"

Micah: "So if I'm learning about a specific part of a larger topic, I'll say, how does this connect to the larger topic or the other smaller things within the topic?"

Larry: "When I approach after I've broken everything down into each section, I look at the section and I'm like, how well do I know this? And then I look at some of the example problems and I go, can I solve this problem?"

Each of these examples also illustrates the means by which these **Interviewees** regulated their processes for learning through an awareness of how they learn, which is another aspect of "metalearning" as an application of metacognition (Biggs, 1988; Flavell, 1979; Jackson, 2004). The rest of the interview data were also rich with examples of self-regulated learning strategies, such as self-monitoring, self-teaching, and self-evaluation, as listed in Tables A.1 through A.7.

5.3.5 How Two Self-Regulating Learning Strategies Employ Reflection

Two examples of self-regulating learning strategies that were identified in Tables 3.7 and 3.8 are self-questioning and self-evaluation, and each of these strategies involves reflection. When self-questioning, students can search for the underlying meaning in a course topic or its key concepts by identifying and exploring incomplete or confusing information, such as "What does this mean?" or "How can I learn this better?" Multiple perspectives or alternative ways of explaining a concept may be revealed, which have been identified as reflection or reflective judgment according to several theoretical models ((Chabon & Lee-Wilkerson, 2006; Hatton & Smith, 1995; Kember et al., 2008).

Self-evaluation can be highly reflective when it leads to self-judgment (Bandura, 1986; Zimmerman, 2000). One form of self-evaluation is measuring competence through comparison to a standard such as expectations for test performance, and seeking causes for one's own satisfactory or poor performance (Zimmerman, 2000). For example, Keith describes using test performance for self-evaluation of competence:

> "So usually, I'll just get my Math class for example, we have about eight lecture videos and then, this is usually around one to two hours long, and then we have a quiz. We have three section quizzes. I feel like those quizzes give me a good idea of how well I understood the material and if I don't perform as well as I thought I should have on those quizzes, then I'll say, "Oh, okay, maybe I should re-watch the videos or maybe I should review this problem. And maybe I should attend office hours because of this."

Self-evaluation can also be used to gauge mastery, especially when reflection is used as a follow-up strategy, in this example by Jeremy:

> "I think in general, studying for me is to really master the material that is being taught in class. I go to lecture to be more introduced to the topic. And then I take time outside of that to work problems or review notes to really

make sure that I get the material and master it so that I can apply it later."

A common example of both self-questioning and self-evaluation by the **Interviewees** was expressed by Hillary as follows:

"Do I understand it, or do I just know how to do it?"

In order to answer this self-question, Hillary needed to critically evaluate her understanding and compare it to her understanding of related prior concepts. This form of self-evaluation resembles reflective thinking or judgment by comparing the understanding of new knowledge to that of existing knowledge, which provides a metric or benchmark for understanding as well as a means of forming relationships between these two types of knowledge (Chabon & Lee-Wilkerson, 2006; Hatton & Smith, 1995; Kember et al., 2008; King & Kitchener, 1994; J. Moon, 2007).

5.4 Summary

First-year engineering students describe their learning approaches and strategies in terms of both reflective and responsive terms. As described in Chapter 2, the surface and surface-achieving learning approaches tend to be responsive and driven by extrinsic goals in order to meet externally-imposed course requirements. The deep and deep-achieving approaches are more likely to be reflective, as they are influenced by intrinsic goals, such as genuine interest in the course material, and/or a self-imposed obligation to attain conceptual knowledge as necessary for ongoing success, especially in technical courses.

Based on the survey results from a 1,200-participant **Study Sample**, and detailed interview data from 15 **Interviewees**, responsive strategies were also exercised to address course requirements and meet specific end goals. Similarly, and using the same sources of data, reflective strategies required additional thought and concentration in order to achieve a meaningful understanding of technical course concepts to apply to problem solving and to integrate new knowledge with existing knowledge in both technical and non-technical courses.

While there were variations in the use of learning approaches and strategies among courses for both the **Study Samples** and the **Interviewees,** the participants in both groups used similar reflective strategies across their science and mathematics courses, with a major emphasis on understanding course concepts and occasionally discovering a need to change their learning strategies to meet the particular demands of a course. There were wider differences in the selection of learning strategies in the engineering and non-technical courses, which could be attributed to the greater variety of topics in these courses, causing students to perceive less of an externally-imposed or easily-identified structure in these courses.

Emerging issues that were further explored in this chapter concerned the absence of the surface learning approach in favor of the surface-achieving or deep-achieving approach, goal orientation in terms of either mastery or performance, and the contributions of reflection to the metacognitive self-regulating learning strategies of self-questioning and self-evaluation. These contributions were not always recognized by **Interviewees**, but were definitely in use, especially when considering how well they thought they understood technical course concepts.

6.0 Conclusions

6.1 Introduction

This chapter builds upon the answers to my research question and sub-questions by describing issues emerging from this study, implications for researchers, administrators, educators, and students, and recommendations for future studies.

Interviewees, for the most part, were clearly more engaged with the material in their technical courses than their non-technical ones, and were much more concerned about achieving high grades, particularly in their science and math courses. I came to this conclusion by recognizing how often the **Interviewees** used examples from these types of courses when describing their learning strategies. Regarding the reflective learning strategies specified in the reflection-related survey questions, both the **Interviewee** and the **Study Sample** groups used the strategies for Kember's Habitual Action, Understanding, and Reflection stages more or less frequently, depending on the course context and learning assessment requirements.

The most important motivation for researchers to continue to study the first-year aspect of student learning in the field of engineering is the fact that the study of learning approaches and strategies used by engineering students is a largely underexplored area of study. Therefore, I provide recommendations for in-depth studies about the relationship between metacognition and reflection, and between reflection and critical thinking. Educators should adopt the mindset that learning should be reinforced at every level, and that students will not necessarily retain everything presented to them in one sitting. Neither should educators at the upper levels automatically assume that their students will retain and be able to retrieve every item of knowledge that they ever learned instantaneously. Strategies for meaningful learning need to be reinforced and adapted to meet the needs of students, which relate to course requirements, in order to derive the necessary meaning for knowledge retention and transfer. A longitudinal study with mapping of strategies used by undergraduate students throughout their curriculum could also inform "next step" scaffolded guidance at different stages, which is adapted to different learning contexts.

6.2 Implications for Future Work

The continued development and reinforcement of meaningful learning approaches and strategies is important to mitigate academic disengagement among first-year engineering students who will soon become rising sophomores, for the reasons outlined in Chapter 1, Section 1.2. A number of studies have shown how strong academic preparation, aided by the continued use of meaningful and effective learning strategies, both before and during the first year of college, can also mitigate attrition from engineering and similar programs during the first year (Allen et al., 2008; Allen & Robbins, 2008; Cherif et al., 2013, 2015; Crede & Kuncel, 2008; Downing, 2009; Geisinger & Raman, 2013; Gore, 2006; Kamali, 2021; Schauss & Peuker, 2014; Scheidt et al., 2019). Two of the more recent studies reported positive results for interventions to promote greater engagement with the study of engineering and mitigate the risk of attrition. The former study included greater student identification with a specific engineering discipline through hands-on applications not normally used during the first year, while the latter provided guided practice in specific academic and non-academic strategies for success as an engineering student (Kamali, 2021; Schauss & Peuker, 2014). Several of the results of these studies were also similar to the successful strategies reported by the **Interviewees** in my study.

Stakeholders with an interest in the results of my study include researchers in engineering education, engineering administrators, engineering educators, and engineering students. The following subsections contain the reasons for a continuation of research in this area of study, newly identified outcomes building on the Kember reflection model, the reinforcement of conceptual knowledge, and several of the ways in which the cognitivist/constructivist theoretical framework could be applied to activities in the engineering classroom.

6.2.1 Implications for Researchers in Engineering Education

Educational researchers, including those in the study of engineering education, seem to still grapple with the nature of knowing and the nature of learning, and attempt to characterize it as either behaviorist, cognitivist, or situated (Newstetter & Svinicki, 2015). It seems that cognitivism seems to be currently prevalent in engineering education, with the promotion of problem solving, the correction of misconceptions, and attention to the process of problem solving as well as the solutions (Newstetter & Svinicki, 2015). Several applications of learning strategies relating to the cognitivist framework that emerged from my study were the identification of metrics for the measurement of learning with understanding (see Chapter 4, Section 4.2.1.2, with examples from Adam and Michael), connections to prior knowledge through reflection (see Chapter 4, Section 4.2.1.2, with examples from Lori and Valerie), and the ultimate responsibility of the learner for their own learning (see Chapter 4, Section 4.2.2.2, with an example from Pete).

Many worthwhile studies in learning approaches and strategies involved undergraduate students from non-specified class years and academic disciplines (Biggs, 1988, 1999; Biggs & Tang, 2011; Crede & Kuncel, 2008; Hartwig & Dunlosky, 2012; Karpicke et al., 2009; Kember et al., 2000; Kornell & Son, 2009; Leung & Kember, 2003; Morehead et al., 2016). The methods and results to be found in these and subsequent studies provide a useful starting point for the further exploration of both cognitive and affective factors in the application of learning approaches and strategies, such as the phenomenon of “metalearning” (Biggs, 1999; Jackson, 2004; Scheidt et al., 2019). However, none of my combinations of methods and results were evident in the prior studies that I investigated, which means that my methods and results could provide a prompt for further exploration in the first-year engineering domain.

In addition, ongoing efforts to assist students in developing stronger conceptual knowledge within their chosen engineering discipline could also be applied to first-year engineering topics, especially those that are widely transferrable to individual engineering disciplinary programs. A large number of my **Interviewees** stressed the importance of understanding concepts for better test performance through understanding, and a few also indicated a need to apply concepts to a variety of contexts both inside and outside the classroom. Additional research in this area could lead to the development of pedagogies to promote "best practices" to use in the engineering classroom to promote inductive learning, or learning by doing, in areas such as project-based learning, experiential learning, service learning, and the interrelationships among course topics within a curriculum (Felder & Brent, 2004, 2005; Geisinger & Raman, 2013).

My adaptation of the Kember reflection questionnaire (Kember et al., 2000) to accommodate different responses for different courses provided the opportunity for differences in the use of reflection among both technical and non-technical courses. This adaptation should be of interest to researchers who study the use of reflection in learning, as well as those who conduct research about engineering student learning at the first-year level. In the former case, the stages in the Kember model could be applied sequentially to determine a progression of reflective thinking within a domain, or, as in my study, non-sequentially, to ascertain the role of context in prompting reflection.

6.2.2 Implications for Administrators in the Higher Education of Engineers

Administrators in higher education have stated that their institutions have an ethical responsibility to provide sufficient support to the students that they admit (Cherif et al., 2015). Their immediate concern might be their students' graduation rate, which reflects on the institution's reputation and its ability to attract new students. A later study by Cherif and colleagues surveyed nearly 1,000 administrators and faculty for proposed improvements to higher education on the national level, where the results revealed that students' academic preparation and readiness for college was the second-highest improvement, exceeded only by greater accessibility to higher education by underrepresented socioeconomic groups (Cherif, Roze, Wajngurt, Overbye, Movahedzadeh & Gialamas, 2018). On this basis, administrators should be amenable to measures that would improve their students' chances for academic success, such as an increased engagement with the process of learning, encouraged by guidance in how to learn as well as what to learn.

For engineering deans and supporting administrators, the question arises as to how to add one more thing to an already packed engineering curriculum (Chachra, D., 2013; Ktoridou & Eteokleous, 2014; Voronov, Basuray, Obuskovic, Simon, Barat & Bilgili, 2017). The answer lies not in adding something new and unrelated to current course topics, but to guide the use of meaningful and highly productive learning strategies, such as reflection, self-questioning, and self-monitoring, to the content that already exists. In order to do so, however, engineering administrators need to provide their faculty with additional resources and additional opportunities to interact with the engineering education research community in order to apply research-based evidence about meaningful learning approaches and strategies into practice at both the first-year and higher levels.

6.2.3 Implications for Engineering Faculty

While the results of my study have indicated that the **Interviewees** and the **Study Samples** already employ certain learning strategies for short-term academic success, such as high grades on tests, these strategies could be made more sustainable through their implementation in upper-level engineering courses. This implementation could also contribute toward meeting the ABET student outcome for "an ability to acquire and apply new knowledge as needed, using appropriate learning strategies" (ABET, 2019). The self-regulating and reflective learning strategies that are listed in Chapter 3, Tables 3.7 and 3.8 and were practiced by many of the **Interviewees** in my study could be applied to course content at any level in an engineering curriculum.

Both first-year and upper-level engineering faculty often assume that their students have retained knowledge and skills from prerequisite courses or admissions requirements that can be instantaneously used in their courses. These faculty are then disappointed when their students do not demonstrate this instant recall, and therefore think that their students are not prepared for college-level work (Cherif et al., 2018, 2014). The promotion of more meaningful learning approaches and strategies, beginning in the first year, enables students to retain more of what they have learned because it fits into their existing body of knowledge (Kember et al., 2008; King & Kitchener, 1994; Moon, 2007).

In particular, learning strategies related to the deep approach to learning, such as the metacognitive and self-regulating strategies that prompt a student to both monitor, question, and assess their learning, increase their probability of success in future course and workplace contexts, where recall and reflection-in-action are everyday activities (Bransford et al., 2000; Bransford, J.D., 1999; Halpern & Hakel, 2003; Schön, 1983). Since faculty want their students to be successful both in their courses and beyond, they should be willing to embed the use of meaningful learning strategies into their course content.

6.2.4 Implications for Engineering Students

Learning approaches and strategies that yield successful outcomes for students help them to develop a strong sense of competence in engineering studies (Deci & Ryan, 2000). Better learning strategies can also lead to higher grades, which students value as proof of their competence for the engineering profession (Kennedy & Upcraft, 2010; Schreiner, 2010). The **Interviewees** in my study built their own sense of competence when they attained a conceptual understanding of technical course material. As a result, their quest for conceptual understanding caused a number of them to adopt deep-achieving and deep learning strategies as a part of their quest for high grades.

A sense of competence is also intrinsically motivating and provides evidence to the student that they are well-suited for their chosen career, as implied in Chapter 2, Section 2.2 (Gore & Hunter, 2010; Kennedy & Upcraft, 2010). Opportunities to develop and improve competence also contribute to a more positive self-concept, and improve self-efficacy (Bong & Skaalvik, 2003).

Students can also enrich their education by practicing the self-regulating and metacognitive learning strategies that were identified in my study, because these strategies, in particular, assist in the development and refinement of expertise, as well as the ability to reason and to transfer or adapt existing knowledge to alternative contexts (Bransford, J.D., 1999; Heywood, 2014; King & Kitchener, 1994; Perry, 1999). Students will also be more interested in what they are learning when they consciously compare new knowledge to prior knowledge and integrate course topics across their curricula both vertically and horizontally.

6.3 Recommendations for Future Investigations and Guided Practice

Several areas for future investigation are described in this section, such as further exploration of the role of reflection as an aid to metacognition and the similarities and differences between reflection and critical thinking. An example of guided practice in self-questioning and self-evaluation is also included, which may be used by educators to encourage reflection and improve metacognition.

6.3.1 Future Investigations

Additional studies involving metacognition and its relationship to learning approaches could include the further exploration of metacognitive knowledge of persons, tasks and strategies (Flavell, 1979; McCord & Matusovich, 2019). Specifically, the knowledge of self is what a student knows or believes about their own knowledge and abilities (McCord & Matusovich, 2019). This knowledge is likely to influence the choice of a surface or deep learning approach in keeping with what the student wants to accomplish (Biggs, 1988). Additional insights into how students evaluate their knowledge and abilities may also help to further explain the student's choice of a "growth" or a "fixed" mindset, although these two states are not mutually exclusive (Dweck, 2015). There may also be similarities between the growth mindset and a tendency to employ the deep learning approach, due to a greater engagement with learning resulting from a desire to learn more.

Educators could benefit from the exploration of their own metacognitive awareness and strategies using, for example, the recently published Inquiry Learning Model (Asy'ari et al., 2019). Another approach to educator metacognition has been suggested by identifying how an educator thinks about their thinking toward teaching, and how these insights might lead to improvements in their teaching (Tanner, 2012). Improvements in metacognition, identified through research, could be as beneficial to educators as they are to students.

My study exhibited a mutually beneficial relationship between metacognition and reflection in the **Interviewees'** use of reflective learning strategies that also proved to be metacognitive, such as self-questioning, self-monitoring, and self-evaluation, all of which were also self-regulating (Ambrose, S.A. et al., 2010; Crede & Kuncel, 2008; Karpicke, 2009). Additional studies could be conducted to better understand how reflection promotes metacognition and how existing metacognitive strategies could be strengthened by reflection.

Studies in metacognition have often included the role of reflection as a facilitator of the metacognitive and self-regulating skills of self-questioning, self-monitoring, and self-evaluation in both technical and non-technical courses (Asy'ari et al., 2019; Dewey, 1933; Ghanizadeh, 2017; Jackson, 2004; Leung & Kember, 2003; Lizzio & Wilson, 2013; McCombs, 1990; Meyer et al., 2015; Tanner, 2012). For example, a 2012 study employed several interventions to teach metacognitive learning strategies in a biology course and included reflective journal assignments in which students assessed the effectiveness of their test preparation strategies in view of recent test performance (Tanner, 2012). Additional studies could be conducted to better understand how reflection promotes metacognition and how existing metacognitive strategies could be strengthened by reflection.

A review linking reflection to the implementation of Biggs' concept of "metalearning" argued that reflection could assist in being aware of and controlling how a student learns (Jackson, 2004). The findings from this review were later extended to strategic remedies for first-year students who were at risk of giving up on higher education (Lizzio & Wilson, 2013). However, my search did not result in studies to further explore the cognitive mechanisms that cause the outcomes of reflection to be helpful to the development of metacognition. This area is worth exploring to better understand why reflection is beneficial to both students and lifelong learners and that these benefits are applicable beyond their study areas of origin.

Educators could benefit from the exploration of their own metacognitive awareness and strategies, using, for example, the recently published Inquiry Learning Model (Asy'ari et al., 2019). Another approach to educator metacognition has been suggested by identifying how an educator thinks about their thinking toward teaching, and how these insights might lead to improvements in their teaching (Tanner, 2012). Improvements in metacognition, identified through research, could be as beneficial to educators as they are to students.

Biggs had extended his findings about learning approaches and metacognition into methods for constructive alignment for educators in order to encourage more students to adopt a deep approach to their learning (Biggs, 1996; Biggs & Tang, 2011). I have already shown how Biggs' work with learning approaches was extended by the Kember group to expand the role of reflection in learning through both parallel and collaborative studies (Biggs et al., 2001; Kember et al., 1999; Kember & Ginns, 2012). Still another area for future work could be the expansion of the constructive alignment approach to more fully incorporate reflection for not only self-directed and self-regulated learning, but also to further explore students' beliefs about knowledge (Moon, 2004).

It would be relatively easy to conflate reflection and critical thinking because of their similarities, but a number of differences exist between them, which could provide alternative pathways for researchers to pursue (Ennis, 2011; King & Kitchener, 1994; Paul & Elder, 2002). As an example of how engineering educators might employ reflection and critical thinking for different outcomes is as follows:

- Request that their students reflect on what they produced in their homework assignments as a way to derive meaning from them and,
- Teach critical thinking as a careful consideration of available evidence before forming a conclusion or constructing an argument.

Reflection and critical thinking are often described and pursued in a mutually exclusive manner. However, the ability to think critically can involve reflection, both in the evaluation of evidence as a way to reconcile uncertainty or about the lack of sufficient information to form a judgment about the soundness of the evidence (Ennis, 2011; King & Kitchener, 1994). In a similar reciprocity, critical thinking can assist reflection by providing a "reality check" on derived meaning for plausibility.

Fortunately, studies on the use of critical thinking in engineering have been disseminated, although they are few and far between (Ceylan & Lee, 2003; Douglas, 2012; Niewoehner, R.J., 2006; Rugarcia et al., 2000). Therefore, additional investigation into this area would considerably expand its body of knowledge. One caveat for the expansion of critical thinking skills into the resolution of engineering problems lies in the fact that such problems are often ill-structured and the logical, systematic process of critical thinking may be stymied (King & Kitchener, 1994). However, reflection may be used to overcome this difficulty, especially when accompanied by other cognitive methods commonly used by engineers, such as making reasonable assumptions, seeking information from a wide variety of sources, and understanding the views of stakeholders.

6.3.2 An Example of Guided Practice in the Use of Self-Questioning and Reflective Learning Strategies

I developed an example of guided practice in reflective learning strategies, primarily self-questioning, which was identified earlier as a reflective and metacognitive self-regulating learning strategy that may reinforce creative and critical thinking abilities. This example, shown in Table 6.1 on the next page, not only demonstrates the value of self-questioning to the ability to retain knowledge, but also informs the desire of the engineering education innovation community to better understand how students learn through the use of critical and creative thinking, which is a common learning outcome (American Society for Engineering Education (ASEE), 2009). Another benefit to this form of guided practice is that students who already reflect on their learning as a strategy could better understand how reflection provides additional meaning to what they are learning.

Table 6.1: An Example of Guided Practice in the Use of Reflection for Learning

Self-Questioning Prompts	**Rationale and Literary Sources**	**Applicable Learning Strategies from my Study Results**
Part 1: Beginning of the Course		
What technical, professional and/or interpersonal skills would you like to learn or improve upon in our course?	Instructor's interest in students' interests promotes engagement with learning through empowerment and caring (Jones, 2009, 2018)	Forming value judgments from what is learned; Planning and goal setting
What did you previously think was always true, but now you know that its truth depends on the situation or context?	Learning via links to prior knowledge (Ambrose, et al., 2010; Chabon & Lee-Wilkerson, 2006; Hatton & Smith, 1995; Kember et al., 2008; King & Kitchener, 1994; J. Moon, 2007)	Comparing new knowledge to prior knowledge using reflection
Part 2: Middle Week of the Course		
What progress have you made toward acquiring the skills that you identified in the first reflection assignment?	Organizing knowledge (Ambrose, et al., 2010)	Self-monitoring and self-evaluating one's learning
What have you encountered in our course that you still find difficult to understand? What could you do to overcome this difficulty?	Seeking help (Biggs, 1988); What does and what does not work (Jackson, 2004)	Seeking help from textbooks, online sources, instructors, or other students; Studying in groups
Real-world engineering problems often contain incomplete information, uncertainty and error. How would you deal with this type of problem?	Uncertainty of knowledge (King & Kitchener, 1994)	Forming value judgments about what is learned; Discovering and exploring patterns in knowledge using reflection
Part 3: End of the Course		
Consider your progress in your group or team project (if applicable): what would you recommend to a future group or team for further investigation?	Assessment of performance; self-evaluation (Ambrose, S.A. et al., 2010; Crede & Kuncel, 2008; Karpicke et al., 2009; McCombs & Marzano, 1990)	Evaluating the use of strategies; Planning and goal setting; Teaching others
What additional progress have you made toward acquiring the skills that you identified at the beginning of the semester?	Achieving mastery; self-evaluation (Ambrose, et al., 2010; McCombs & Marzano, 1990)	Self-monitoring and self-evaluating one's learning; Employing interleaved practice

At each stage of the course, using examples of “good,” “better,” and “best” reflective responses, students would work individually or in small groups to discern, inductively, why some of their responses were more meaningful than the others (American Society for Engineering Education (ASEE), 2009; Felder & Brent, 2005). An in-class debrief would also be conducted after each assignment, where each small group or pre-selected individuals would then share their findings with others in a class discussion. I would also pre-select several other students to ask the reporting students, “Why is that?” to probe for additional insights through reflection-in-action (Schön, 1983). The class discussion should also address the barriers to reflection, such as lack of time, energy, or willingness to think beyond what is apparent.

A suitable instrument to assess progress in reflection is both formative and summative, i.e., it provides feedback to the student about their attempts at reflection and exhibits progress in the ability to exercise and describe reflective thought over time. The grading rubric for reflection-based homework assignments described below contains a scale for each question. This scale is given as an example:

Skills Transfer to Upcoming Courses

Identifies skill(s) to transfer to another course clearly and convincingly	3
Identifies skill(s) to transfer to another course, with limited rationale	2
Identifies a non-specific use (e.g., " I can use this in my job as an engineer.")	1

I chose to list this scale because the students’ responses would indicate whether they recognize where the skills in the first-year engineering courses could be used in their upper-level courses, which indicates that they are able to apply new knowledge to alternative contexts (Hatton & Smith, 1995; Kember et al., 2008; King & Kitchener, 1994; Moon, 2004). These criteria resemble guidance given by Kember and Ginns (2012), which employs criteria for the four stages of reflection in Kember's model: Habitual Action, Understanding, Reflection, and Critical Reflection.

6.4 Concluding Summary

Engineering students want to believe that what they are studying is worthwhile and that they can use the knowledge that they gain during their first year of study to be successful in the future. A major barrier to their success is academic disengagement, based, in part, on students' perceptions that they are not competent enough to meet the challenges of higher level courses, as discussed in Section 2.2.1. A strong first-year preparation has been shown to mitigate the effects of future academic challenges and may also reduce attrition from engineering programs. Therefore, I conducted this study to learn more about how first-year engineering students employ learning strategies and their underlying approaches to both technical and non-technical courses, primarily in order to produce insights for meaningful classroom activities to reinforce existing learning strategies and practice new ones.

It is important to characterize how first-year engineering students learn, as well as to scrutinize what they are learning and how they perceive its value. A trove of educational research supports my own experience in the classroom and indicates that all first-year engineering students could benefit from additional reinforcement of meaningful learning approaches and strategies initiated by their educators.

Engineering students need to develop and maintain a strong foundation in fundamental technical and non-technical skills in order to become engineers. A variety of academic and student-life-related reasons exist as to why sophomore students, including those who study engineering, may become disengaged from their studies; a number of these reasons have been documented in the literature that informed my study, as described in Chapter 2. As an engineering educator, I was primarily concerned with the existing state of first-year engineering students' learning approaches and strategies, which would inform interventions to mitigate academic disengagement as my students entered their engineering degree programs without the benefit of the academic support systems to which they had become accustomed in high school and during their first year of college. I also intend to pursue several of the suggested research areas described above, and these areas should also be considered by other educational researchers who, together with educators, can promote meaningful student learning over all types of courses as a way to mitigate potential academic disengagement and attrition.

Researchers in engineering education have already explored many aspects of the undergraduate engineering student experience and what they mean for the engineering profession. Additional research that combines learning approaches with metacognition and reflection, as in the further exploration and implementation of self-regulating learning strategies, would provide convincing evidence to engineering educators that they should provide appropriate guided practice in order to better serve the needs of their students beyond the first year. Appropriate guided practice in meaningful learning strategies, combined with appropriate forms of assessment, can be integrated with current and future engineering course content. By working together, engineering education researchers, administrators, and faculty can all become better facilitators of learning.

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Appendix A: Coded Interview Responses

Table A.1: Product-related Approaches and Strategies: Responses to, "What is your overall purpose for studying?"
(T = Technical courses; NT = Non-Technical courses)

			Learning Approach				**Course Type**	
Interviewee	***a priori* Codes**	**Examples from the Data**	**Surface**	**Surface-Achieving**	**Deep-Achieving**	**Deep**	**T**	**NT**
John	Memorization: relationships among definitions, terms, or formulas	Be able to work problems without notes			X		X	
	Self-directing and self-regulating one's learning using metacognition, e.g. self-evaluation	Master the subject with "muscle memory"			X		X	
	Working practice problems and practice tests	Learn how to apply concepts to test problems				X	X	
Michael	Forming value judgments about what is learned	More focus on what is interesting to him				X	X	
	Forming value judgments about what is learned; Planning and goal setting	Reduces what he doesn't enjoy to a routine and "just get it done"		X			X	X
	Monitoring and evaluating the use of strategies; Planning and goal setting	Balance between necessities and interests				X	X	X
	Self-directing and self-regulating one's learning using metacognition, e.g. self-monitoring and self-teaching	Likes to learn new things				X	X	X
Hillary	Forming value judgments about what is learned	Respect for her subjects and her work in them			X		X	X
	Forming value judgments about what is learned	Cost of school creates urgency and importance			X		X	X

	Self-directing and self-regulating one's learning using metacognition, e.g. self-evaluation	Needs to study a lot because knowledge doesn't come automatically to her				X	X	
	Self-directing and self-regulating one's learning using metacognition, e.g. self-questioning	Is engineering what she really wants?				X	X	
Valerie	Forming value judgments about what is learned	Studies more when she enjoys the subject				X	X	X
	Monitoring and evaluating the use of strategies	Good prep for exams is key to good grades			X		X	
Nathan	Forming value judgments about what is learned; Planning and goal setting	Studies longer when material is interesting				X	X	X
Nathan	Monitoring and evaluating the use of strategies; Planning and goal setting	Studies more when course relates to major and/or career		X			X	
	Monitoring and evaluating the use of strategies	Studies for the grade		X				X
Micah	Monitoring and evaluating the use of strategies	Study to do better on assignments and tests		X			X	
	Planning and goal setting	Build knowledge for future courses				X	X	X
Larry	Forming value judgments about what is learned; self-directing and self-regulating one's learning through metacognition, e.g., self-evaluation	Decide how much expertise he needs for the test			X		X	
	Monitoring and evaluating the use of strategies	Study to succeed on tests		X			X	
	Monitoring and evaluating the use of strategies	Rely on memorization for tests		X				X
	Work practice problems and practice tests	Solve problems to prepare for the test			X		X	

Keith	Forming value judgments about what is learned; Planning and goal setting	Take STEM courses more seriously		X			X	
	Forming value judgments about what is learned; Planning and goal setting	Study less for courses irrelevant to career path	X				X	X
	Monitoring and evaluating the use of strategies	Study for the grade		X				X
	Self-directing and self-regulating one's learning through metacognition, e.g., self-monitoring and self-evaluation	Seeks conceptual understanding				X	X	
Adam	Forming value judgments about what is learned	Underlying purpose is how a course contributes to his degree		X			X	X
	Self-directing and self-regulating one's learning through metacognition, e.g., self-monitoring and self-evaluation	Gain a further understanding of course material, especially for tests			X		X	X
Pete	Forming value judgments about what is learned	Can't memorize a process for all problem solving	X				X	
	Memorization	Memorize terms and what they mean		X				X
	Monitoring and evaluating the use of strategies	Study for the test		X			X	
Pete	Working practice problems and practice tests	Use concepts to solve problems			X		X	
Jeremy	Monitoring and evaluating the use of strategies	Explore the topic through practice problems or reviewing notes			X		X	
	Self-directing and self-regulating one's learning through metacognition, e.g., self-monitoring and self-evaluation	Master the course material			X		X	X

Mark	Forming value judgments about what is learned; Planning and goal setting	Study to pass the test or quiz		X				X	X
	Forming value judgments about what is learned	Forget about the topic until the final exam	X					X	X
Lori	Forming value judgments about what is learned	Study to pass classes and earn degree so that I can get a job	X					X	X
Kira	Monitoring and evaluating the use of strategies	Study to perform well in classes		X				X	X
	Self-directing and self-regulating one's learning through metacognition, e.g., self-monitoring and self-evaluation	Develop conceptual understanding					X	X	
Michelle	Monitoring and evaluating the use of strategies	Study to do better in classes		X				X	X

Table A.2: Product-related Approaches and Strategies: Responses to, "How can you tell when you understand something?"
(T = Technical courses; NT = Non-Technical courses)

			Learning Approach					
Interviewee	***a priori* Codes**	**Examples from the Data**	**Surface**	**Surface-Achieving**	**Deep-Achieving**	**Deep**	**Course Type**	
John	Teaching others to offer help and reinforce own understanding	When I can teach it to others so that they understand it fully			X		T	NT
	Teaching others to offer help and reinforce own understanding	I am more motivated to learn it well when others need my help				X	X	
							X	
Michael	Checking results	Checking results to see if they make sense				X	X	
	Finding real-life examples of course material	When I can visualize a concept using a real-life example			X			
	Self-directing and self-regulating one's learning using metacognition, e.g., self-teaching	Self-teaching to identify what each variable means				X	X	
							X	
Hillary	Forming value judgments about what is learned	Certain topics are easier to learn than others			X		X	
	Self-directing and self-regulating one's learning using metacognition, e.g., self-questioning and self-evaluation	Ask myself: do I comprehend it, or am I just doing it? Insists on understanding concepts			X			
	Self-directing and self-regulating one's learning using metacognition, e.g., self-evaluation	Mentions her self-awareness of need to study				X	X	
							X	X
Valerie	Working practice problems and practice tests	When I can apply the concept to multiple problems on a practice test		X				
	Working practice problems and practice tests	Take full advantage of all course-provided materials to maximize understanding		X			X	
							X	X

Nathan	Teaching others to offer help and reinforce own understanding	When I can teach something to others correctly, and so that they understand it				X		
							X	X
Micah	Teaching others to offer help and reinforce own understanding	When I can teach something to others and they can understand it			X			
	Working practice problems and practice tests	When I can solve problems without help		X			X	X
							X	
Larry	Working practice problems and practice tests	When I can solve problems without help		X				
							X	
Keith	Forming value judgments about what is learned	Rely on performance on quizzes, tests and practice tests to gauge understanding		X				
							X	
Adam	Self-directing and self-regulating one's learning using metacognition, e.g., self-monitoring and self-evaluation	When I feel invested and engaged in the material				X	X	
	Teaching others to offer help and reinforce own understanding	When I can explain a concept orally, clearly, and easily—teach myself and others simultaneously				X		
							X	X
Pete	Working practice problems and practice tests	After I work a lot of practice problems without help from people or notes			X			
							X	
Jeremy	Teaching others to offer help and reinforce own understanding	When I can teach it to others			X			
	Working practice problems and practice tests; checking results	After I work a lot of practice problems without help from people or notes, and if answers are correct after checking			X		X	X
							X	

Mark	Memorization	When I can recall a process or a formula readily		X				
	Working practice problems and practice tests	When I can work a problem without using notes or other forms of help					X	
							X	
Lori	Patterns in knowledge through reflection	When I can recognize where knowledge is cumulative, when the basics lead to the big picture, or when some event led to another event.				X		
							X	X
Kira	Teaching others to offer help and reinforce own understanding	When I can teach it to others so that they understand it fully				X		
							X	
Michelle	Self-directing and self-regulating one's learning using metacognition, e.g., self-monitoring and self-evaluation	I ask myself if I understand it, and decide whether or not I actually do			X		X	X
	Teaching others to offer help and reinforce own understanding	When I can teach it to others			X			

Table A.3: Process-related Approaches and Strategies: Responses to, "How do you decide what to study next?"
(T = Technical courses; NT = Non-technical courses)

			Learning Approach				Course Type	
Interviewee	***a priori* Codes**	**Examples from the Data**	**Surface**	**Surface-Achieving**	**Deep-Achieving**	**Deep**	**T**	**NT**
John	Forming value judgments about what is learned	Begin with most difficult material			X		X	X
	Forming value judgments about what is learned	If two assignments are due at the same time, begin with the one where the risk of failure is greater			X		X	
	Planning and goal setting	I should start planning by deadlines		X			X	X
Michael	Employing interleaved practice, i.e., come back to it later	Take breaks between subjects and tasks			X		X	X
	Forming value judgments about what is learned	Begin with math and other less interesting subjects to just get them done			X		X	
	Forming value judgments about what is learned	Do enjoyable tasks later on			X		X	X
	Planning and goal setting	Work two days ahead whenever possible				X	X	X
	Planning and goal setting	Add buffer time to allow for unexpected events and underestimated task duration				X	X	
Hillary	Planning and goal setting	Plan at least one week ahead of time			X		X	X
	Planning and goal setting	Identify due dates first, then allocate time to assignments			X		X	X
	Planning and goal setting	Add buffer time to allow for unexpected events and underestimated task duration				X	X	
	Planning and goal setting	Divide task into increments and work on it over a number of days				X	X	

Valerie	Forming value judgments about what is learned	Plan to spend more time on subjects that are easier to learn		X			X	
	Planning and goal setting	Begin with preparing for the next test or next assignment due		X			X	X
Nathan	Forming value judgments about what is learned	Focus on preparing for the next text		X			X	X
	Planning and goal setting	Does not plan in advance, just studies in the time available	X				X	X
Micah	Forming value judgments about what is learned	Depends on his mood: sometimes begins with easy assignments, then difficult ones, and conversely			X		X	
	Planning and goal setting	Uses a planner to record class times and due dates for assignments and tests		X			X	X
Larry	Planning and goal setting	Uses a planner to record assignments and due dates		X				
	Planning and goal setting	Tries to balance his workload among the days available before a deadline, such as deciding how many days in advance to study for a test			X		X	X
Keith	Forming value judgments about what is learned	If two assignments are due at the same time, begin with the one that I enjoy the most		X			X	X
	Planning and goal setting	Begin with the task having the next deadline		X			X	X
Adam	Forming value judgments about what is learned	Begin with difficult concepts			X		X	
	Interleaved practice, i.e, come back to it later	Include breaks in study schedule				X	X	X
	Planning and goal setting	Plan time for each subject in increments				X	X	X

Pete	Compare new knowledge to prior knowledge using reflection	More comfortable when material is related to what he’s learned before				X	X	X
	Forming value judgments about what is learned	Begin with more difficult or least comfortable material			X		X	X
	Forming value judgments about what is learned	Gauge level of comfort according to what’s on the test		X			X	X
	Planning and goal setting	Study for only one test at a time		X			X	
Jeremy	Planning and goal setting	Plan according to deadlines		X			X	X
	Planning and goal setting	Study for longer time as test date gets closer					X	X
	Planning and goal setting	Include time to review notes as well as work practice problems			X		X	
Mark	Compare new knowledge to prior knowledge using reflection; forming value judgments about what is learned	Rely on relationship to prior knowledge to decide whether something is easy or hard			X		X	
	Forming value judgments about what is learned	Begin with courses with the lowest grades		X			X	X
	Forming value judgments about what is learned	Prioritize STEM courses over non-STEM because they are harder		X			X	
Lori	Forming value judgments about what is learned	Begin with the shorter assignments, then do the longer ones		X			X	X
	Forming value judgments about what is learned	Free up time for more important assignments			X		X	
Kira	Forming value judgments about what is learned	Determine order of urgency, depending on deadlines or difficulty with the topic or course			X		X	
Michelle	Forming value judgments about what is learned	Do the quicker-to-finish tasks first, then the longer ones		X			X	X
	Planning and goal setting	Respond to deadlines first if they become urgent		X			X	X

Table A.4: Process-related Approaches and Strategies: Responses to, "What are your most useful methods for learning course material?"

(T = Technical courses; NT = Non-Technical courses)

			Learning Approach				Course Type	
Interviewee	***a priori* Codes**	**Examples from the Data**	**Surface**	**Surface-Achieving**	**Deep-Achieving**	**Deep**	**T**	**NT**
John	Note taking from lectures and/or textbooks	Take good notes in lecture and on readings		X				X
	Patterns in knowledge through reflection	"Recognizing kind of historical patterns"			X			X
	Working practice problems and practice tests	Work practice problems, both supplied by the course and online				X	X	
	Working practice problems and practice tests	Think about concepts when working problems				X	X	
Michael	Forming value judgments about what is learned	Likes to write, but it has its place			X			X
	Self-directing/self-regulating one's learning using metacognition, e.g. self-teaching	Practicing with new material				X	X	
	Self-directing/self-regulating one's learning using metacognition, e.g. self-teaching	Figuring out what a software does on his own				X	X	
Hillary	Forming value judgments about what is learned	Textbook is often more credible than the instructor			X		X	
	Planning and goal setting	Divide work into chunks over days			X		X	
	Seek help from textbooks or online sources	Seek alternative explanations				X	X	
	Self-directing/self-regulating one's learning using metacognition, e.g. self-evaluation	Work for a while, then take a break or work on something else				X	X	X

Valerie	Forming value judgments about what is learned	Non-STEM material is more structured than STEM material			X			X
	Memorization	Memorize by writing things down multiple times		X				X
	Working practice problems and practice tests	Do a lot of practice problems provided with the course		X			X	
Nathan	Memorization	Review the material		X				X
	Memorization	Work a Quizlet®		X				X
	Seek help with understanding and problem solving from one or more expert individuals	Ask professor for help while doing a problem		X			X	
	Working practice problems and practice tests	Work practice problems		X			X	
Micah	Memorization	Memorize by repeating material multiple times		X				X
	Seeking help from textbooks or online sources	Read the textbook for background knowledge		X			X	X
	Working practice problems and practice tests	Work practice problems		X			X	
Larry	Compare new knowledge to prior knowledge using reflection	Recognize that knowledge is cumulative				X	X	X
	Compare new knowledge to prior knowledge using reflection	Recall prior knowledge for current use			X		X	X
	Memorization	Memorize definitions		X				X
	Monitoring and evaluating the use of strategies	Figure out what method works for each type of problem			X		X	
	Planning and goal setting	Balance the workload among the days available for it			X		X	X
	Self-directing/self-regulating one's learning using metacognition, e.g. self-teaching	Break down material from large parts to small parts			X		X	X

Keith	Employing interleaved practice, i.e, come back to it later; Self-directing/self-regulating learning using metacognition, e.g., self-monitoring	Don't have too much in one day - spread it out over several days				X	X	X
	Employing interleaved practice, i.e, come back to it later	Build in buffer time			X		X	X
	Planning and goal setting	Spread the material out over the available time			X		X	X
	Self-directing/self-regulating one's learning using metacognition, e.g. self-monitoring	Spend more time on what he doesn't understand			X		X	X
	Self-directing/self-regulating one's learning using metacognition, e.g. self-monitoring	Check for understanding			X		X	X
Adam	Memorization	Use flashcards and Quizlet® for self-testing		X				X
	Seeking help from online sources	View online videos for alternative ways to explain what is difficult				X	X	
	Working practice problems and practice tests	Work practice problems and practice tests			X		X	
Pete	Forming value judgments about what is learned	STEM content is cumulative, but non-STEM content is not		X				X
	Memorization	Look over important terms and concepts		X				X
	Self-directing/self-regulating one's learning using metacognition, e.g. self-evaluation	Focus on weaknesses and mitigate them		X			X	
	Working practice problems and practice tests	Work practice tests because they "cover everything I need to know."		X			X	X
Jeremy	Self-directing and self-regulating one's learning through metacognition, e.g., self-teaching	Use active learning to engage with a foreign language: write it, speak it, think in it.				X		X

	Working practice problems and practice tests	Work practice problems to get to the concept behind them			X		X	
	Working practice problems and practice tests	Work practice tests		X			X	
Mark	Seeking help from textbooks or online sources	Review the instructor’s lecture videos		X			X	
	Seeking help from textbooks or online sources	Review all of the course materials, such as notes, textbook and any available videos		X				X
	Working practice problems and practice tests; patterns in knowledge through reflection	Work different types of practice problems				X	X	
Lori	Seeking help from textbooks or online sources	It depends on the class. Like physics last year, or last semester, I went to all my lectures, but I didn't really find them very useful so I ended up learning a lot of stuff from the textbook.			X		X	
	Seeking help from textbooks or online sources	Whereas this semester in like linear, I'm not really a fan of the lectures or the textbooks. I go out and find my own resources.			X		X	
Kira	Patterns in knowledge through reflection; Self-directing and self-regulating one’s learning using metacognition, e.g. self-evaluation.	Develop a systemic understanding of a concept.			X		X	X
	Working practice problems and practice tests	Work a lot of practice problems because repetition promotes understanding.			X		X	
Michelle	Note taking from lectures and/or textbook	Write formulas in the margins of class notes.			X		X	

	Note-taking from lectures and/or textbook	Write a study guide.				X	X	X
	Self-directing and self-regulating one’s learning using metacognition, e.g. self-evaluation	Review exam answers and correct them, as necessary.			X	X	X	X

Table A.5: Process-related Approaches and Strategies: Responses to, "How do you handle difficult material?"
(T = Technical courses; NT = Non-Technical courses)

			Learning Approach				**Course Type**	
Interviewee	**a priori Codes**	**Examples from the Data**	**Surface**	**Surface-Achieving**	**Deep-Achieving**	**Deep**	**T**	**NT**
John	Planning and goal setting; Self-directing and self-regulating one's learning using metacognition, e.g., self-questioning	Break it into smaller chunks, then synthesize them into the big picture				X	X	
	Seeking help with understanding and problem solving from one or more individuals; Seeking help from online sources	Afterwards: seek help from others, go online, come back to it later, memorize it (in that order)			X		X	
Michael	Discover and explore patterns in knowledge through reflection	Apply AI principles to find patterns and relationships in knowledge				X	X	
	Seeking help from textbooks and online sources	Seek explanations in textbooks or online			X		X	
	Self-directing and self-regulating one's learning using metacognition, e.g., self-evaluation	Self-evaluate to find deficiencies			X		X	X
	Working practice problems and practice tests	Do additional practice problems				X	X	
Hillary	Interleaved practice, i.e, come back to it later	Come back to it later if necessary				X	X	
	Seeking help from textbooks and online sources	Try alternative sources			X		X	
	Seeking help with understanding and problem solving from one or more individuals	When seeking help, trust instructor more than peers			X		X	
	Self-directing and self-regulating one's learning using metacognition, e.g., self-questioning and self-monitoring	Self-monitor: do I understand this?					X	X

Valerie	Interleaved practice, i.e., come back to it later	Take a break to regain perspective				X	X	X
	Seeking help from textbooks and online sources	Go to online sources, peers and/or instructor			X		X	
	Self-directing and self-regulating one's learning using metacognition, e.g., self-evaluation	Try not to become frustrated with it				X	X	X
Nathan	Seeking help with understanding and problem solving from one or more individuals	Go to a friend first, then office hours		X			X	
	Seeking help with understanding and problem solving from one or more individuals	Ask a question about it in class			X		X	X
Micah	Seeking help with understanding and problem solving from one or more individuals	Later: ask friends or go to office hours			X		X	
	Self-directing and self-regulating one's learning using metacognition, e.g., self-teaching	Teach self while practicing			X		X	
	Self-directing and self-regulating one's learning using metacognition, e.g., self-questioning	Ask self: is there a different way to look at this?				X	X	
	Working practice problems and practice tests	Practice with it a lot			X		X	
Larry	Discovering and exploring patterns and relationships in knowledge through reflection	Look for patterns among concepts			X		X	
	Discovering and exploring patterns and relationships in knowledge through reflection	Identify how things work as a key to understanding concepts				X	X	
	Planning and goal setting	Break down difficult or large-scope material into smaller chunks				X	X	X

Keith	Seeking help from textbooks and online sources	Review the textbook or course videos		X			X	
	Seeking help from textbooks and online sources	Afterwards: go online, then to office hours			X		X	
Adam	Comparing new knowledge to prior knowledge using reflection	Need to refresh prior knowledge to meet demands and make understanding easier			X		X	
	Discovering and exploring patterns and relationships in knowledge through reflection	STEM course material is interrelated and builds on itself				X	X	
	Seeking help from textbooks and online sources	Rely on different videos for alternative explanations			X		X	
Pete	Seeking help from textbooks and online sources	Use online resources if necessary			X		X	
Pete	Self-directing and self-regulating one's learning using metacognition, e.g., self-evaluation	Reminds himself that he has confidence in his ability, and persists				X	X	
	Self-directing and self-regulating one's learning using metacognition, e.g., self-teaching and self-monitoring	Proceed linearly, one step at a time, using course resources			X		X	
	Working practice problems and practice tests	Do additional practice problems			X		X	
Jeremy	Seeking help from textbooks and online sources	Seek help from online sources			X		X	
	Seeking help with understanding and problem solving from one or more individuals	Seek help from peers			X		X	X
	Seeking help with understanding and problem solving from one or more individuals	Afterwards: go to office hours		X			X	X
Mark	Seeking help from textbooks and online sources	Watch the posted lecture video		X			X	

	Seeking help from textbooks and online sources	Seek help from online sources			X		X	
	Seeking help with understanding and problem solving from one or more individuals	Afterwards: go to office hours			X		X	
	Working practice problems and practice tests	Do more practice problems			X		X	
Lori	Memorization	Keep going over material until I understand it			X		X	X
	Seeking help with understanding and problem solving from one or more individuals	Go to office hours to check her understanding		X			X	
Kira	Seeking help from textbooks and online sources	View YouTube videos about the material		X			X	
	Self-directing and self-regulating one's learning through metacognition, e.g., self-teaching and self-monitoring	Seek help with alternative ways to explain or teach something				X	X	X
Michelle	Memorization	Read the material multiple times		X			X	X
	Seeking help from textbooks and online sources	Re-watch videos			X		X	
	Seeking help with understanding and problem solving from one or more individuals	Go to a friend for help		X			X	
	Seeking help with understanding and problem solving from one or more individuals	Go to office hours after all of the above			X		X	

Table A.6: Process-related Approaches and Strategies: Responses to, "What kinds of questions do you ask yourself while you are studying?"

(T = Technical courses; NT = Non-Technical courses)

			Learning Approach				**Course Type**	
Interviewee	**a priori Codes**	**Examples from the Data**	**Surface**	**Surface-Achieving**	**Deep-Achieving**	**Deep**	**T**	**NT**
John	Checking results	Do these numbers make sense?				X	X	
	Self-directing and self-regulating one's learning using metacognition, e.g., self-questioning	Do I understand the theoretical aspects?			X		X	
	Self-directing and self-regulating one's learning using metacognition, e.g., self-questioning	Self-questions the results to problems, but still needs an answer key		X			X	
Michael	Finding real-world examples of course material	Applies concepts to real-world examples that he can see or visualize				X	X	
Hillary	Forming value judgments about what is learned; Self-directing and self-regulating one's learning using metacognition, e.g., self-monitoring	Demands to understand because it isn't automatic for her				X	X	X
	Self-directing and self-regulating one's learning using metacognition, e.g., self-evaluation	Do I understand it, or just know how to do it?			X		X	
Valerie	Memorization	Do I really understand what I'm doing, or just memorizing how to do the problem?				X	X	
Nathan	Finding real-world examples of course material	What is an example of this in the real world?				X	X	
Micah	Planning and goal setting;	How does this item connect to the larger topic or smaller items within the topic?				X	X	

	Self-directing and self-regulating one’s learning using metacognition, e.g., self-questioning							
	Planning and goal setting; Self-directing and self-regulating one’s learning using metacognition, e.g., self-evaluation	How can I learn this better?			X		X	
Larry	Self-directing and self-regulating one’s learning using metacognition, e.g., self-teaching	Assesses his level of knowledge with respect to the test		X			X	X
	Self-directing and self-regulating one’s learning using metacognition, e.g., self-evaluation	How well do I know each section?			X		X	
	Self-directing and self-regulating one’s learning using metacognition, e.g., self-monitoring	Can I solve this [example] problem?			X		X	
Keith	Self-directing and self-regulating one’s learning using metacognition, e.g., self-evaluation	Check for understanding		X			X	X
Adam	Compare new knowledge to prior knowledge using reflection	What things did you learn earlier that might make this less difficult?			X		X	
	Discovering and exploring patterns in knowledge through reflection	How will this item be integrated into a more complex concept?				X	X	
	Finding real-world examples of course material	For non-technical: how can I relate this concept to the real world?			X			X
	Self-directing and self-regulating one’s learning using metacognition, e.g., self-monitoring and self-evaluation	Do I fully understand that part of the concept?				X	X	
Pete	Forming value judgments about what is learned	Comment: avoid blind plug and chug because you don’t understand how to apply the process to the problem				X	X	

	Self-directing and self-regulating one's learning using metacognition, e.g., self-monitoring and self-evaluation	Do I understand what I'm doing and why?				X	X	
	Self-directing and self-regulating one's learning using metacognition, e.g., self-questioning	What is the difference between what works and what doesn't work?			X		X	
Jeremy	Memorization	Did I understand what I just read?			X			X
	Self-directing and self-regulating one's learning using metacognition, e.g., self-monitoring	Am I trying to understand this material?			X		X	
	Self-directing and self-regulating one's learning using metacognition, e.g., self-monitoring and self-evaluation	Am I absorbing the material?				X	X	
Mark	Checking results	Checks problem solutions			X		X	X
	Checking results	Troubleshoots problems to detect sources of errors			X		X	X
Mark	Memorization	Does not ask questions consciously	X				X	X
Lori	Self-directing and self-regulating one's learning using metacognition, e.g., self-monitoring and self-evaluation	Do I know how to do this problem?		X			X	
	Self-directing and self-regulating one's learning using metacognition, e.g., self-evaluation	Do I understand why I did this problem in this way?			X		X	
Kira	Teaching others to offer help and reinforce own understanding	Can I teach this to someone else?			X		X	X
Michelle	Discovering and exploring patterns in knowledge through reflection	What are the connections, patterns and relationships in the course material?				X	X	

Table A.7: Process-related Approaches and Strategies: Responses to, "How do you view study groups, i.e.., students who get together to study?"

(T = Technical courses; NT = Non-Technical courses)

			Learning Approach				**Course Type**	
Interviewee	**a priori Codes**	**Examples from the Data**	**Surface**	**Surface-Achieving**	**Deep-Achieving**	**Deep**	**T**	**NT**
John	Monitoring and evaluating the use of strategies	Large groups are ineffective—too many distractions			X		X	X
	Seeking help with understanding and problem solving from one or more individuals	Will get together with a few friends via text			X		X	
Michael	Monitoring and evaluating the use of strategies	Small groups are better than large ones			X		X	
	Teaching others to offer help and reinforce own understanding; seeking help with understanding and problem solving from one or more individuals	We can help each other				X	X	
Hillary	Seeking help with understanding and problem solving from one or more individuals	Seek an impartial source of help instead			X		X	X
	Self-directing and self-regulating one's learning using metacognition, e.g., self-evaluation	Not very helpful because students are elitist about what they think they know				X	X	
Valerie	Checking results	Review mistakes on quizzes and why they were made		X			X	
	Seeking help with understanding and problem solving from one or more individuals	Focus on answers to problems that were already given: does anyone have any issues with them?		X			X	

Nathan	Seeking help with understanding and problem solving from one or more individuals	Good for bouncing ideas off others and maybe find a better way to do something			X			
	Teaching others to offer help and reinforce own understanding; seeking help with understanding and problem solving from one or more individuals	Opportunity to explain a concept to someone else			X		X	
Micah	Seeking help with understanding and problem solving from one or more individuals	Detect mistakes with the help of peers			X		X	
	Seeking help with understanding and problem solving from one or more individuals	Good for bouncing ideas off others to figure out if something is correct or incorrect			X		X	
	Teaching others to offer help and reinforce own understanding	Use my tutoring experience to teach others			X		X	
Larry	Employing interleaved practice, i.e, come back to it later	Useful at the end to check understanding before a test			X		X	X
	Seeking help with understanding and problem solving from one or more individuals; Teaching others to offer help and reinforce own understanding	Useful at the beginning to define the scope of what is to be learned			X		X	X
Keith	Seeking help with understanding and problem solving from one or more individuals	Good to study with a group to prepare for a test		X			X	
Adam	Forming value judgments about what is learned	Some students use them as an excuse for productivity				X		
	Seeking help with understanding and problem solving from one or more individuals	Could learn a better problem-solving strategy from other students				X		

	Self-directing and self-regulating one's learning using metacognition, e.g., self-questioning	Prefers to study alone and rely on self-testing				X		
Pete	Monitoring and evaluating the use of strategies	Emphasis on hands-on learning			X		X	
	Seeking help with understanding and problem solving from one or more individuals	Good for bouncing ideas off others			X		X	X
Jeremy	Seeking help with understanding and problem solving from one or more individuals; teaching others to offer help and reinforce own understanding	Not a regular participant, but he will help a friend or ask a friend for help		X			X	X
	Teaching others to offer help and reinforce own understanding	Teaching others helps his understanding			X		X	X
Mark	Monitoring and evaluating the use of strategies; self-directing and self-regulating one's learning using metacognition, e.g. self-monitoring	Self-awareness of how he acts in a study group; prefers to study alone because he can study when he wants to		X			X	X
Lori	Seeking help with understanding from one or more individuals	Asking peers for help when the professor is not available; focus on solving a type of problem		X			X	
Kira	Seeking help with understanding from one or more individuals; monitoring and evaluating the use of strategies	Effectiveness depends on group dynamics; how the group views studying			X		X	X
Michelle	Planning and goal setting	Have an agenda or plan			X		X	X
	Seeking help with understanding and problem solving from one or more individuals	Choose a study group consisting of friends		X			X	X
	Teaching others to offer help and reinforce own understanding	Respect for everyone's needs				X	X	X

Appendix B: Reflection-Related Survey Results

Table B.1: Reflection-Related Survey Results: Interviewees—ENGE 1215, Fall 2020

		Course:	ENGE 1215	ENGE 1215	ENGE 1215	ENGE 1215	ENGE 1215	ENGE 1215	ENGE 1215	ENGE 1215
		Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
		Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:		Nathan	2	2	4	4	2	4	2	2
StrongAgree	5	Pete	4	3	4	3	4	4	1	3
StrongAgree/ GenAgree	4.5	Lori	4	4	4	2	2	2	2	1
GenAgree	4	Jeremy	5	4	5	4	4	4	1	2
Neither/ GenAgree	3.5	Adam	3	2	3	2	3	2	2	1
Neither	3	John	4	4	4	4	4	3	3	1
GenDisagree/ Neither	2.5	Micah	2	2	4	4	4	5	2	2
GenDisagree	2	Hillary	5	4	4	4	4	4	2	2
GenDisagree/ StrongDisagree	1.5	Michelle	4	4	4	2	4	3	2	2
Strongly Disagree	1	Larry	4	4	4	3	3	4	3	2
		Keith	4	4	4	4	5	5	3	3
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.		Kira	4	4	5	2	4	5	3	5
		Valerie	5	5	4	1	4	4	3	1
		Michael	4	3	4	4	3	4	2	2
		Median Values:	**4.0**	**4.0**	**4.0**	**3.5**	**4.0**	**4.0**	**2.0**	**2.0**
		Agreement:	GenAgree	GenAgree	GenAgree	Neither/ GenAgree	GenAgree	GenAgree	GenDisagree	GenDisagree
		Quartile 1	4.00	3.00	4.00	2.00	3.00	3.25	2.00	1.25
		Quartile 3	4.00	4.00	4.00	4.00	4.00	4.00	4.00	3.00
		IQR	**0.00**	**1.00**	**0.00**	**2.00**	**1.00**	**0.75**	**2.00**	**1.75**

Table B.2: Reflection-Related Survey Results: Interviewees—Science Courses, Fall 2020

		Course:	Science	Science	Science	Science	Science	Science	Science	Science
		Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
		Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:		Nathan	2	2	5	4	2	4	2	4
StrongAgree	5	Pete	2	2	3	4	4	4	1	3
StrongAgree/ GenAgree	4.5	Lori	2	3	5	5	3	5	2	4
GenAgree	4	Jeremy	5	4	5	4	4	4	1	2
Neither/ GenAgree	3.5	Adam	3	3	3	3	3	3	3	3
Neither	3	John	5	4	4	5	2	4	3	1
GenDisagree/ Neither	2.5	Micah	1	1	5	4	2	4	3	5
GenDisagree	2	Hillary	2	2	4	5	4	5	5	5
GenDisagree/ StrongDisagree	1.5	Michelle	2	2	5	5	3	4	2	3
Strongly Disagree	1	Larry	1	1	4	4	3	4	3	4
		Keith	4	4	4	4	5	5	3	3
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.		Kira	2	2	5	5	3	5	3	5
		Valerie	4	2	4	4	4	5	3	4
		Michael	2	1	5	5	3	5	2	4
		Median Values:	**2**	**2**	**4**	**4**	**3**	**4**	**3**	**4**
		Agreement:	GenDisagree	GenDisagree	GenAgree	GenAgree	Neither	GenAgree	Neither	GenAgree
		Quartile 1	2	2	4	4	3	4	2	3
		Quartile 3	3.75	3	4	4.75	5	5	4	4.5
		IQR	**1.75**	**1**	**0**	**0.75**	**2**	**1**	**2**	**1.5**

Table B.3: Reflection-Related Survey Results: Interviewees—Math Courses, Fall 2020

		Course:	Math	Math	Math	Math	Math	Math	Math	Math
		Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
		Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:		Nathan	2	2	5	4	3	4	2	3
StrongAgree	5	Pete	2	2	3	4	4	4	1	3
StrongAgree/ GenAgree	4.5	Lori	2	3	5	5	3	1	2	4
GenAgree	4	Jeremy	5	4	5	4	4	4	1	2
Neither/ GenAgree	3.5	Adam	3	3	3	3	3	3	3	3
Neither	3	John	5	5	5	5	1	4	1	1
GenDisagree/ Neither	2.5	Micah	1	2	4	4	4	4	4	2
GenDisagree	2	Hillary	1	1	5	5	4	5	3	5
GenDisagree/ StrongDisagree	1.5	Michelle	2	2	4	5	3	4	2	3
Strongly Disagree	1	Larry	1	1	4	4	4	4	3	4
		Keith	4	4	4	4	4	5	3	3
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.		Kira	3	3	5	5	3	5	3	5
		Valerie	4	4	4	3	2	4	3	4
		Michael	1	1	5	5	3	5	2	4
		Median Values:	**2**	**3**	**4**	**4**	**3**	**4**	**3**	**3**
		Agreement:	GenDisagree	Neither	GenAgree	GenAgree	Neither	GenAgree	Neither	Neither
		Quartile 1	1	2	4	4	3	4	2	3
		Quartile 3	3.75	3	4	4	5	4	4	4
		IQR	**2.75**	**1**	**0**	**0**	**2**	**0**	**2**	**1**

Table B.4: Reflection-Related Survey Results: Interviewees—Non-Technical Courses, Fall 2020

		Course:	Non-technical	Non-technical	Non-technical	Non-technical	Non-technical	Non-technical	Non-technical	Non-technical
		Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
		Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:		Nathan	2	2	4	4	3	4	2	4
StrongAgree	5	Pete	2	2	3	4	4	4	1	3
StrongAgree/ GenAgree	4.5	Lori	3	3	3	3	3	3	3	3
GenAgree	4	Jeremy	5	4	5	4	2	4	1	2
Neither/ GenAgree	3.5	Adam	2	2	2	2	2	2	2	2
Neither	3	John	3	3	3	3	3	3	3	3
GenDisagree/ Neither	2.5	Micah	4	4	4	2	2	4	3	2
GenDisagree	2	Hillary	5	4	4	3	3	3	5	2
GenDisagree/ StrongDisagree	1.5	Michelle	3	2	5	5	3	4	4	4
Strongly Disagree	1	Larry	3	4	4	3	4	4	3	2
		Keith	4	4	4	4	4	5	3	3
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.		Kira	4	3	4	2	3	5	4	5
		Valerie	4	4	2	2	5	3	4	1
		Michael	4	4	3	2	3	4	2	3
		Median Values:	**4**	**4**	**4**	**3**	**3**	**4**	**3**	**3**
		Agreement:	GenAgree	GenAgree	GenAgree	Neither	Neither	GenAgree	Neither	Neither
		Quartile 1	3	3	3	2	3	3	2	2
		Quartile 3	4	4	4	4	4	4	4	4
		IQR	**1**	**1**	**1**	**2**	**1**	**1**	**2**	**2**

Table B.5: Reflection-Related Survey Results: Study Sample—ENGE 1215, Fall 2020

			Course:	ENGE 1215	ENGE 1215	ENGE 1215	ENGE 1215	ENGE 1215	ENGE 1215	ENGE 1215	ENGE 1215
			Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
			Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:											
StrongAgree	5		Total StrongAgree	224	190	324	118	303	261	109	103
StrongAgree/ GenAgree	4.5										
GenAgree	4		Total GenAgree	548	491	662	492	611	592	250	235
Neither/ GenAgree	3.5										
Neither	3		Total Neither	233	269	155	331	243	255	416	391
GenDisagree/ Neither	2.5										
GenDisagree	2		Total GenDisagree	184	239	69	224	54	99	332	327
GenDisagree/ StrongDisagree	1.5										
Strongly Disagree	1		Total StrongDisagree	35	35	14	59	13	17	117	168
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.			**Median Values:**	4	4	4	3	4	4	3	3
			Agreement:	GenAgree	GenAgree	GenAgree	Neither	GenAgree	GenAgree	Neither	Neither
			Quartile 1	3	3	4	3	3	3	2	2
			Quartile 3	4	4	5	4	4	4	4	4
			IQR	1	1	1	1	1	1	2	2

Table B.6: Reflection-Related Survey Results: Study Sample—Science Courses, Fall 2020

		Course:	Science	Science	Science	Science	Science	Science	Science	Science
		Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
		Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:										
StrongAgree	5	Total StrongAgree	90	89	750	503	218	384	131	376
StrongAgree/ GenAgree	4.5									
GenAgree	4	Total GenAgree	320	268	359	507	441	565	228	452
Neither/ GenAgree	3.5									
Neither	3	Total Neither	188	251	86	139	360	194	417	224
GenDisagree/ Neither	2.5									
GenDisagree	2	Total GenDisagree	421	407	16	58	164	69	302	112
GenDisagree/ StrongDisagree	1.5									
Strongly Disagree	1	Total StrongDisagree	205	209	13	17	41	12	146	60
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.		**Median Values:**	2	2	5	4	4	4	3	4
		Agreement:	GenDisagree	GenDisagree	StrongAgree	GenAgree	GenAgree	GenAgree	Neither	GenAgree
		Quartile 1	2	2	4	4	3	4	2	3
		Quartile 3	4	4	5	5	4	5	4	5
		IQR	2.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0

Table B.7: Reflection-Related Survey Results: Study Sample—Math Courses, Fall 2020

			Course:	Math	Math	Math	Math	Math	Math	Math	Math
			Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
			Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:											
StrongAgree	5		Total StrongAgree	94	81	753	585	243	422	152	409
StrongAgree/ GenAgree	4.5										
GenAgree	4		Total GenAgree	297	251	355	464	467	553	224	438
Neither/ GenAgree	3.5										
Neither	3		Total Neither	196	230	85	118	322	184	411	232
GenDisagree/ Neither	2.5										
GenDisagree	2		Total GenDisagree	388	374	19	45	155	51	280	102
GenDisagree/ StrongDisagree	1.5										
Strongly Disagree	1		Total StrongDisagree	249	288	12	12	37	14	157	43
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.			**Median Values:**	2	2	5	4	4	4	3	4
			Agreement:	GenDisagree	GenDisagree	StrongAgree	GenAgree	GenAgree	GenAgree	Neither	GenAgree
			Quartile 1	2	2	4	4	3	4	2	3
			Quartile 3	4	4	5	5	4	5	4	5
			IQR	2	2	1	1	1	1	2	2

Table B.8: Reflection-Related Survey Results: Study Sample—Non-Technical Courses, Fall 2020

		Course:	Non-Technical	Non-Technical	Non-Technical	Non-Technical	Non-Technical	Non-Technical	Non-Technical	Non-Technical
		Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
		Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:										
StrongAgree	5	Total StrongAgree	274	262	211	144	217	134	235	120
StrongAgree/ GenAgree	4.5									
GenAgree	4	Total GenAgree	543	579	417	317	478	392	471	245
Neither/ GenAgree	3.5									
Neither	3	Total Neither	257	253	399	429	311	382	363	419
GenDisagree/ Neither	2.5									
GenDisagree	2	Total GenDisagree	115	111	163	242	174	251	127	276
GenDisagree/ StrongDisagree	1.5									
Strongly Disagree	1	Total StrongDisagree	35	19	34	92	44	65	28	164
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.		**Median Values:**	4	4	4	3	4	3	4	3
		Agreement:	GenAgree	GenAgree	GenAgree	Neither	GenAgree	Neither	GenAgree	Neither
		Quartile 1	3	3	3	2	3	2	3	2
		Quartile 3	4	4	4	4	4	4	4	4
		IQR	1	1	1	2	1	2	1	2

Table B.9: Reflection-Related Survey Results: Interviewees—ENGE 1216, Spring 2021

			Course:	ENGE 1216	ENGE 1216	ENGE 1216	ENGE 1216	ENGE 1216	ENGE 1216	ENGE 1216	ENGE 1216
			Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
			Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:			Nathan	4	4	4	2	2	5	3	2
StrongAgree	5		Pete	4	4	4	4	4	4	3	3
StrongAgree/ GenAgree	4.5		Lori	4	5	4	2	2	2	2	2
GenAgree	4		Jeremy	5	2	4	5	4	4	3	2
Neither/ GenAgree	3.5		Adam	4	4	4	2	3	2	2	1
Neither	3		John	3	3	4	4	3	3	2	2
GenDisagree/ Neither	2.5		Micah	2	2	2	2	4	4	2	2
GenDisagree	2		Hillary	4	4	4	3	5	4	3	2
GenDisagree/ StrongDisagree	1.5		Michelle	4	4	4	3	3	3	2	2
Strongly Disagree	1		Larry	4	5	5	2	4	3	3	1
			Keith	4	5	5	4	3	3	3	3
			Kira	4	4	4	4	4	4	4	4
			Valerie	4	4	3	2	5	4	2	1
			Michael	4	4	4	4	4	4	4	4
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.			**Median Values:**	4	4	4	3	4	4	3	2
			Agreement:	GenAgree	GenAgree	GenAgree	Neither	GenAgree	GenAgree	Neither	GenDisagree
			Quartile 1	4	4	4	2	3	3	2	2
			Quartile 3	4	4	4	4	4	4	3	2.75
			IQR	0	0	0	2	1	1	1	0.75

Table B.10: Reflection-Related Survey Results: Interviewees—Science Courses, Spring 2021

		Course:	Science	Science	Science	Science	Science	Science	Science	Science
		Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
		Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:		Nathan	2	2	5	5	2	5	3	5
StrongAgree	5	Pete	3	1	4	4	4	4	3	4
StrongAgree/ GenAgree	4.5	Lori	2	5	5	5	3	5	2	4
GenAgree	4	Jeremy	4	3	5	5	4	5	3	4
Neither/ GenAgree	3.5	Adam	1	1	5	5	4	5	5	5
Neither	3	John	3	3	5	4	2	4	1	2
GenDisagree/ Neither	2.5	Micah	1	1	5	5	2	4	2	4
GenDisagree	2	Hillary	2	2	5	5	4	5	3	4
GenDisagree/ StrongDisagree	1.5	Michelle	2	2	4	4	4	4	2	4
Strongly Disagree	1	Larry	2	2	5	4	4	4	3	4
		Keith	4	4	5	4	3	3	3	3
		Kira	4	4	4	4	4	4	4	4
		Valerie	2	4	5	4	5	5	2	3
		Michael	4	4	4	4	4	4	4	4
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.		**Median Values:**	2	2.5	5	4	4	4	3	4
		Agreement:	GenDisagree	GenDisagree/ Neither	StrongAgree	GenAgree	GenAgree	GenAgree	Neither	GenAgree
		Quartile 1	2	2	4.25	4	3	4	2	4
		Quartile 3	3.75	4	5	5	4	5	3	4
		IQR	1.75	2	0.75	1	1	1	1	0

Table B.11: Reflection-Related Survey Results: Interviewees—Math Courses, Spring 2021

			Course:	Math	Math	Math	Math	Math	Math	Math	Math
			Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
			Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:			Nathan	2	2	5	5	2	5	4	5
StrongAgree	5		Pete	2	1	4	4	4	4	3	4
StrongAgree/ GenAgree	4.5		Lori	2	4	5	5	3	5	2	4
GenAgree	4		Jeremy	4	3	5	5	4	5	3	4
Neither/ GenAgree	3.5		Adam	1	1	5	5	4	5	3	4
Neither	3		John	3	4	5	4	1	4	1	2
GenDisagree/ Neither	2.5		Micah	1	1	5	5	2	4	2	5
GenDisagree	2		Hillary	1	1	5	5	2	5	3	4
GenDisagree/ StrongDisagree	1.5		Michelle	2	2	5	4	4	4	2	2
Strongly Disagree	1		Larry	2	2	5	4	4	4	3	4
			Keith	4	4	5	4	3	3	3	3
			Kira	4	4	4	4	4	4	4	4
			Valerie	2	4	4	4	3	4	2	3
			Michael	4	4	4	4	4	4	4	4
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.			**Median Values:**	2	2.5	5	4	3.5	4	3	4
			Agreement:	GenDisagree	GenDisagree/ Neither	StrongAgree	GenAgree	Neither/ GenAgree	GenAgree	GenAgree	GenAgree
			Quartile 1	2	1.25	4.25	4	2.25	4	2	3.25
			Quartile 3	3.75	4	5	5	4	5	3	4
			IQR	1.75	2.75	0.75	1	1.75	1	1	0.75

Table B.12: Reflection Inventory Results: Interviewees—Non-Technical Courses, Spring 2021

		Course:	Non-Technical	Non-Technical	Non-Technical	Non-Technical	Non-Technical	Non-Technical	Non-Technical	Non-Technical
		Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
		Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:		Nathan	5	5	5	5	2	5	1	1
StrongAgree	5	Pete	3	1	4	4	4	4	3	4
StrongAgree/ GenAgree	4.5	Lori	3	2	2	2	2	2	2	3
GenAgree	4	Jeremy	5	3	4	5	4	4	3	3
Neither/ GenAgree	3.5	Adam	4	4	3	1	2	1	2	1
Neither	3	John	4	4	4	4	4	4	1	1
GenDisagree/ Neither	2.5	Micah	4	2	2	2	4	2	2	2
GenDisagree	2	Hillary	4	4	4	3	4	5	5	3
GenDisagree/ StrongDisagree	1.5	Michelle	4	3	4	4	3	3	4	3
Strongly Disagree	1	Larry	3	3	3	3	3	3	3	3
		Keith	5	3	5	4	3	3	3	3
		Kira	3	3	3	3	3	3	3	3
		Valerie	4	4	5	4	3	4	4	3
		Michael	4	4	4	4	4	4	4	4
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.		**Median Values:**	4	3	4	4	3	3.5	3	3
		Agreement:	GenAgree	Neither	GenAgree	GenAgree	Neither	Neither/GenAgree	Neither	Neither
		Quartile 1	3.25	3	3	3	3	3	2	2.25
		Quartile 3	4	4	4	4	4	4	3.75	3
		IQR	0.75	1	1	1	1	1	1.75	0.75

Table B.13: Reflection-Related Survey Results: Study Sample—ENGE 1216, Spring 2021

			Course:	1216	1216	1216	1216	1216	1216	1216	1216
			Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
			Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:											
StrongAgree	5		Total StrongAgree	296	225	268	119	300	247	89	96
StrongAgree/ GenAgree	4.5										
GenAgree	4		Total GenAgree	539	488	662	433	565	578	232	187
Neither/ GenAgree	3.5										
Neither	3		Total Neither	213	238	182	338	267	261	383	356
GenDisagree/ Neither	2.5										
GenDisagree	2		Total GenDisagree	144	223	88	267	79	105	384	373
GenDisagree/ StrongDisagree	1.5										
Strongly Disagree	1		Total StrongDisagree	30	48	22	65	11	31	134	210
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.			**Median Values:**	4	4	4	3	4	4	3	3
			Agreement:	GenAgree	GenAgree	GenAgree	Neither	GenAgree	GenAgree	Neither	Neither
			Quartile 1	3	3	4	2	3	3	2	2
			Quartile 3	4	4	4	4	4	4	4	3
			IQR	1	1	0	2	1	1	2	1

Table B.14: Reflection-Related Survey Results: Study Sample—Science Courses, Spring 2021

			Course:	Science	Science	Science	Science	Science	Science	Science	Science
			Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
			Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:											
StrongAgree	5		Total StrongAgree	79	72	768	561	195	352	142	345
StrongAgree/ GenAgree	4.5										
GenAgree	4		Total GenAgree	234	223	351	485	424	602	256	479
Neither/ GenAgree	3.5										
Neither	3		Total Neither	190	209	81	130	356	208	382	220
GenDisagree/ Neither	2.5										
GenDisagree	2		Total GenDisagree	438	437	14	35	200	44	305	125
GenDisagree/ StrongDisagree	1.5										
Strongly Disagree	1		Total StrongDisagree	281	281	8	11	47	16	137	53
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.			**Median Values:**	2	2	5	4	4	4	3	4
			Agreement:	GenDisagree	GenDisagree	StrongAgree	GenAgree	GenAgree	GenAgree	Neither	GenAgree
			Quartile 1	2	2	4	4	3	4	2	3
			Quartile 3	4	3	5	5	4	5	4	5
			IQR	2	1	1	1	1	1	2	2

Table B.15: Reflection Inventory Results: Study Sample—Math Courses, Spring 2021

			Course:	Math	Math	Math	Math	Math	Math	Math	Math
			Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
			Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:											
StrongAgree	5		Total StrongAgree	85	74	781	599	202	382	139	353
StrongAgree/ GenAgree	4.5										
GenAgree	4		Total GenAgree	247	224	343	464	420	597	236	498
Neither/ GenAgree	3.5										
Neither	3		Total Neither	165	200	77	114	348	182	386	217
GenDisagree/ Neither	2.5										
GenDisagree	2		Total GenDisagree	410	403	13	35	192	47	322	112
GenDisagree/ StrongDisagree	1.5										
Strongly Disagree	1		Total StrongDisagree	315	321	8	10	60	14	139	42
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.			**Median Values:**	2	2	5	4	4	4	3	4
			Agreement:	GenDisagree	GenDisagree	StrongAgree	GenAgree	GenAgree	GenAgree	Neither	GenAgree
			Quartile 1	1	1	4	4	3	4	2	3
			Quartile 3	4	3	5	5	4	5	4	5
			IQR	3	2	1	1	1	1	2	2

Table B.16: Reflection-Related Survey Results: Study Sample—Non-Technical Courses, Spring 2021

			Course:	Non-Technical	Non-Technical	Non-Technical	Non-Technical	Non-Technical	Non-Technical	Non-Technical	Non-Technical
			Kember-Based Reflection Question:	As long as I can remember handout material for exams or assignments, I do not have to think too much.	If I follow what the lecturer says, I do not have to think too much in this course.	This course requires me to understand concepts taught by the lecturer.	In this course, I have to continually think about the material that I am being taught.	I sometimes question the way others do something and try to think of a better way.	I often re-appraise my experience so I can learn from it and improve for my next performance.	This course has challenged some of my firmly held ideas.	As a result of this course, I have changed my normal way of studying.
			Kember Reflection Stage:	Habitual Action	Habitual Action	Understanding	Understanding	Reflection	Reflection	Critical Reflection	Critical Reflection
Data and Median Scale:											
StrongAgree	5		Total StrongAgree	293	215	251	145	184	197	134	109
StrongAgree/ GenAgree	4.5										
GenAgree	4		Total GenAgree	498	466	585	365	430	485	301	217
Neither/ GenAgree	3.5										
Neither	3		Total Neither	262	321	274	383	403	369	428	419
GenDisagree/ Neither	2.5										
GenDisagree	2		Total GenDisagree	126	161	94	262	161	129	253	310
GenDisagree/ StrongDisagree	1.5										
Strongly Disagree	1		Total StrongDisagree	43	59	18	67	44	42	106	167
Method: calculate a median value for each question, then use the scale to assign a Likert agreement. Calculate IQR to describe the spread among the data.			**Median Values:**	4	4	4	3	4	4	3	3
			Agreement:	GenAgree	GenAgree	GenAgree	Neither	GenAgree	GenAgree	Neither	Neither
			Quartile 1	3	3	3	2	3	3	2	2
			Quartile 3	4	4	4	4	4	4	4	4
			IQR	1	1	1	2	1	1	2	2