“Will They Revolt?”:
An Examination of Student Response to Types of Instruction in the Engineering Discipline

by

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DEDICATION

To my parents: for believing I could achieve anything I ever set my mind to and doing everything in their power to make sure I had the means with which to do it;

To my children: let this be proof that you can do anything you set your mind to and know that I will do everything in my power to help you achieve it.

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ABSTRACT

Researchers have long emphasized the need to improve the quality of undergraduate teaching through the use of evidence-based instructional practices (EBIP), particularly for courses in the Science, Technology, Engineering, and Mathematics fields. Despite research supporting the benefits of EBIP in the engineering field, the response from faculty to incorporate a diversity of practices in their classrooms has been mixed. Prior research has found that there are a number of barriers to the adoption of these practices, including student resistance to active learning. Concerns about student resistance, whether evidenced through formal course evaluations or expressed in other ways, has an alarming effect on instructors' willingness to adopt EBIP.

This study seeks to explain the relationship between student response to various types of instruction in their prior and current courses, the frequency with which each type of instruction is used in engineering courses, and how students ultimately evaluate their courses and instructors. The following broader research questions guide this study:

1. What types of instruction are being used in introductory engineering courses at a large research university?
2. How do students respond to different kinds of instruction in these courses? How does their previous experience with different kinds of instruction influence their response to its use in their current course?

3. What relationships exist between prior response, current response, the frequency with which each type of instruction is used in the current course, and how students subsequently evaluate the course and instructor?

To answer the research questions in this study, I employed a mixed methods approach to data collection and analysis, integrating quantitative and qualitative data. Specifically, I randomly selected one large, gateway course from each of the five largest engineering disciplines in the College of Engineering at the University of Michigan. From a total population of 539 students, 242 students participated in two surveys, and 20 students (who completed both surveys) participated in one of five focus groups.

I discovered that the perceived use of EBIP practices in these five courses at the University of Michigan shows promise of more active types of instruction being used in these engineering classrooms. Additionally, I found that students in this sample often have similar positive responses to constructive and active types of instruction as they do passive ones. In contrast, I found that students often placed a lower value on the interactive type of instruction examined in this study, and based on focus groups, found that this was often caused by poor prior experiences with group work in past courses. Furthermore, through a hierarchical multiple regression model, I found relationships between student evaluations and students' prior response to the passive type of instruction and current response to active, constructive, and interactive types of instruction. I also found that the frequency with which each type of instruction is used is associated with similar increases/decreases in students' evaluation of the course and instructor.

While my findings suggest that instructors may need to worry less about negative student response to these practices, future research should focus on how to positively engage students in these practices, and institutions should support the use of instructor strategies to highlight the benefits of EBIP to the students in their classrooms.

Chapter 1: Introduction

Researchers have long emphasized the need to improve the quality of undergraduate teaching through the use of evidence-based instructional practices (EBIP), particularly for courses in the Science, Technology, Engineering, and Mathematics (STEM) fields. For example, the President's Council of Advisors on Science and Technology (PCAST) recommended in their report, *Engage to excel: Producing one million additional college graduates with degrees in science,* that undergraduate STEM education should "catalyze widespread adoption of empirically validated teaching practices" (2012, p. ii). To this end, government agencies and higher education institutions have committed a vast amount of time and resources to developing and documenting the effectiveness of EBIP. More recently, several reports have focused on promoting this type of instructional change in the field of engineering. These reports, such as the American Society for Engineering Education's *Creating a Culture for Scholarly and Systematic Innovation in Engineering Education* (Jamieson & Lohmann, 2009) and *Innovation with Impact* (Jamieson & Lohmann, 2012), as well as the National Academy of Engineering's *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees* (Malcom & Feder, 2016), have all presented the importance of EBIP in preparing future engineers for the workforce in the 21st century.

Although they lack a formal definition, EBIP, also referred to as "nontraditional teaching strategies" (Felder & Brent, 2009; Hake, 1998; Johnson & Dasgupta, 2005) or "research-based instructional strategies" (RBIS) (Borrego, Cutler, Prince, Henderson, & Froyd, 2013; Henderson

& Dancy, 2007), generally follow a set of guiding principles. These principles include: 1) the involvement of students in a learning process based on more than listening to an instructor teach or watching him or her solve problems, 2) an emphasis on the transfer of skills useful for students' development rather than the simple diffusion of knowledge, 3) the engagement of students in activities (e.g., writing, discussing, presenting), and 4) the examination of students' values and emotions in the instructional process (Bonwell & Eison, 1991). In contrast, "traditional" approaches predominantly feature lecture-style instruction, make little or no use of strategies that engage students in the learning process (Hake, 1998), and do not involve collaborative learning (Johnson & Dasgupta, 2005).

The benefits of EBIP, such as active learning, are well documented. In their meta-analysis of 158 studies, Johnson, Johnson, and Smith (1991) found that students participating in a course that encompassed some form of active learning generally scored approximately one-half standard deviation, or 6%, higher than their peers in traditional lecture courses on examinations and student concept inventories. Furthermore, when they examined the failure rates of students in both nontraditional and traditional courses across 67 different studies, Johnson and colleagues found that students in traditional lecture courses were 50% more likely to fail their course when compared to their peers in nontraditional learning courses.

Other studies have shown that specific teaching practices can be effective for educating an increasingly diverse student body. Research has suggested that ineffective teaching practices and competitive climates in undergraduate science and engineering programs are barriers to student success in these fields, particularly for women and students of color (Colbeck, Cabrera, & Terenzini, 2000; Seymour & Hewitt, 1997; Strenta, Elliott, Adair, Matier, & Scott, 1994). However, Colbeck et al. (2000) found that the effects of these barriers are often mitigated when faculty use nontraditional learning practices and provide and entertain feedback. Furthermore, researchers have found that these practices increase the retention rate of students, particularly in STEM fields (Barnett, 2014; Braxton, Jones, Hirschy, & Hartley III, 2008; Braxton, Milem, & Sullivan, 2000; Haak, HilleRisLambers, Pitre, & Freeman, 2011). Put together, calls for increasing the number and diversity of students obtaining STEM degrees could be answered by introducing a wider diversity of instructional practices into the classroom.

Despite research supporting the benefits of EBIP in the engineering field, the translation from research into practice (i.e., incorporating a diversity of practices in the classroom) has been slow (Friedrich, Sellers, & Burstyn, 2007; Handelsman et al., 2004; Hora, Ferrare, & Oleson, 2012; PCAST, 2012; Singer, Nielsen, & Schweingruber, 2012). In their investigation of the transition of EBIP in the engineering classroom, Cutler, Borrego, Prince, Henderson, and Froyd (2012) found that, out of 221 faculty surveyed, approximately 97% had knowledge about EBIP, but only 52% of these faculty were actively using it in their classrooms. Of the remaining 48%, 11% had not tried any of these practices in their classrooms, and the other 37% had tried these practices previously, but had abandoned them since their initial use. This lack of use and abandonment of EBIP is particularly concerning for researchers advocating for the increased use of these activities.

If the use of EBIP in the engineering classroom benefits students and faculty have knowledge of these strategies, why are faculty either choosing not to incorporate these practices in their curricula, or abandoning them altogether? Research on faculty decisions about their teaching practices has identified a number of barriers to the adoption of these practices, including student resistance to active learning, questions about the efficacy of these practices, restrictions in course structure due of lack of time and/or content flexibility, and institutional policies and reward structures (Dancy & Henderson, 2010; Eddy, Converse, & Wenderoth, 2015; Felder & Brent, 1996; Finelli, Daly, & Richardson, 2014; Fraser et al., 2014; Froyd, Borrego, Cutler, Prince, & Henderson, 2013; Henderson & Dancy, 2007; Hora, 2012; Kiemer, Gröschner, Pehmer, & Seidel, 2015; Prince, Borrego, Cutler, Henderson, & Froyd, 2013; Seidel & Tanner, 2013). Concerns about student resistance (Borrego, Froyd, & Hall, 2010; Dancy & Henderson, 2012; Finelli et al., 2014; Fraser et al., 2014; Seidel & Tanner, 2013), whether evidenced through formal course evaluations or expressed in other ways, has an alarming effect on instructors' willingness to adopt EBIP. Consequently, understanding how students respond to new types of instruction and identifying ways to reduce student resistance are essential for removing a key barrier that hinders instructors from adopting EBIP.

In addition to these concerns about student resistance, there also remains a question regarding how students' prior responses to different types of instruction might impact their responses to the same activities in the future. Specifically, if a student had a poor experience with group work in a previous course, does this impact how he or she will respond to the same activity in the future? Thus, understanding more about the role of students' prior experiences is essential to understanding other factors that might influence students' responses to subsequent active learning instructional strategies.

The Proposed Study

The purpose of my research study is to examine the relationship between students' prior and current responses to various types of instruction, the frequency with which each type of instruction is used in engineering courses, and how students ultimately evaluate their courses and instructors. Specifically, I use data on the types of instruction encountered in introductory engineering courses and undergraduate students' responses to these types of instruction to develop a list of factors influencing students' evaluation of the course and instructor. I have already been engaged in this work as a research assistant. In prior studies with this research team (e.g., DeMonbrun et al., 2017; Nguyen et al., 2017a; Shekhar et al., 2015), we developed a framework to better understand students' responses to various types of instruction used in the engineering classroom. According to this framework, instructors can impact student response by using different types of instruction (e.g., lecturing, implementing group work, using individual problem solving) and by using strategies to overcome resistance (e.g., explaining the evidence-based benefits of an activity or facilitating student engagement). For this dissertation study, I adapt our framework to include the effect of student response to different types of instruction in their previous courses, while also examining the relationships between the frequency with which each type of instruction is used in the classroom, how students' respond to this type of instruction in their current courses, and how students ultimately evaluate the course and instructor (Figure 1). A more detailed discussion of this framework and its application to this study is offered at the end of Chapter 2.

Given the importance of gateway courses (i.e., introductory, discipline-specific, core courses that most engineering majors take) on the persistence of students in engineering fields (Gainen, 1995; Seymour & Hewitt, 1997; Springer, Stanne, & Donovan, 1999; Suresh, 2006), my study investigates student behaviors across these gateway courses in five engineering disciplines at the University of Michigan. Gateway courses were chosen for several reasons. First, the use of discipline-specific engineering courses reduces the number of extraneous variables. For example, choosing discipline-specific courses likely reduces the variation in students' experiences in prior courses due to the strict course pathways in these engineering disciplines (i.e., most students will follow a similar progression of courses). Second, students

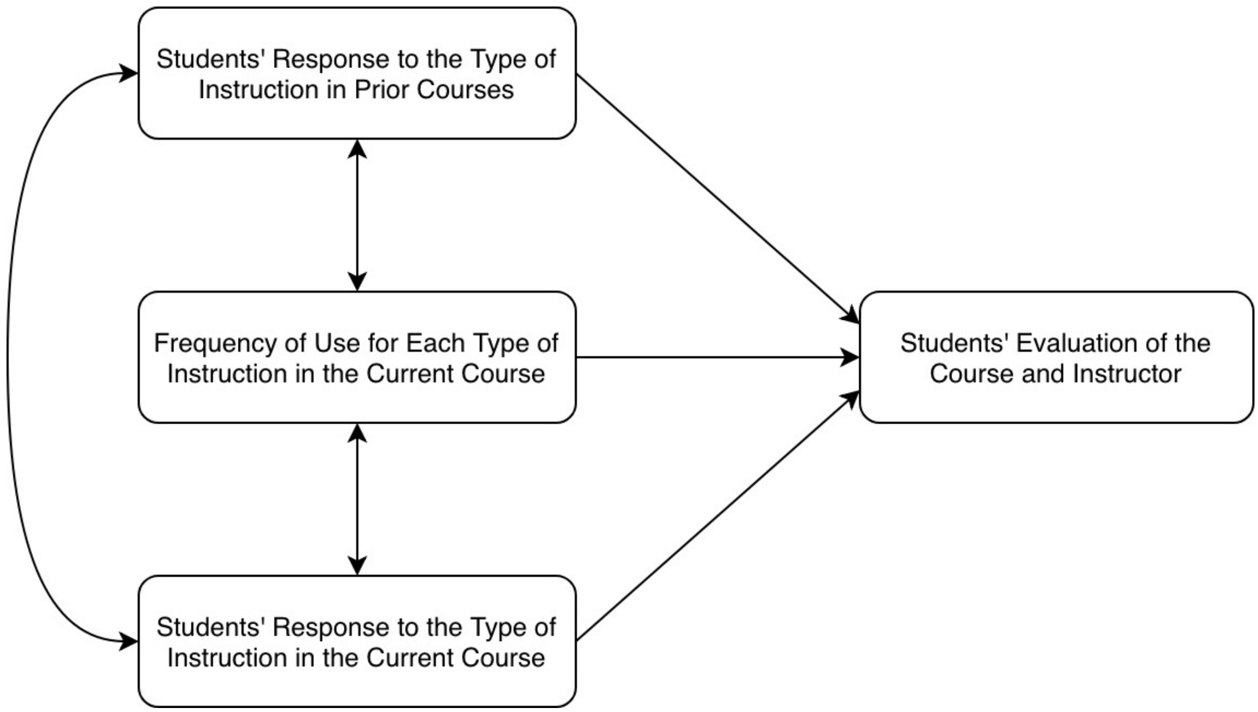

Figure 1. Conceptual framework illustrating the relationship between types of instruction, students' prior and current response to the type of instruction, and students' evaluation of the course and instructor.

in upper-division disciplinary courses may react differently to these practices due to their prior exposure. Third, these introductory gateway courses typically enroll larger numbers of students (mostly ranging from 50 to 150 students), which allows for larger sample sizes and enriches the significance of the impact of these types of instruction on larger courses. Finally, research has found that greater student attrition is generally attributed to poor instruction that often occurs early in the curriculum, and this study investigates whether or not these findings apply to this research context (Gainen, 1995; Seymour & Hewitt, 1997; Suresh, 2006).

Significance of the Study

There are several significant contributions for my research. First, my study will examine engineering courses broadly across five different engineering disciplines to undercover the types of instruction students perceive to be used in these classrooms. In other words, I will provide descriptive statistics for these five randomly-selected courses to check the "pulse" of the types of instruction being used in these classrooms.

Second, my study will explore how students respond to EBIP in the engineering classroom. This is important given that prior research has indicated that fear of student resistance is a barrier for faculty in implementing these practices in their classrooms (Borrego, Froyd, & Hall, 2010; Dancy & Henderson, 2012; Finelli et al., 2014; Fraser et al., 2014; Froyd et al., 2013; Henderson & Dancy, 2007; Seidel & Tanner, 2013). My research adds to the empirical literature that has investigated the extent to which these perceived reactions truly exist. Similarly, there is some reason to believe that students with negative prior experiences might respond differently to an activity than those with a more positive experience. For example, students who have encountered positive experiences answering questions posed by the instructor in previous courses may be more likely to respond positively to the use of this type of instruction in subsequent courses because they draw upon these prior positive experiences as knowledge for how to participate in the activity, as compared to students with a poor prior experience with this same type of instruction.

Third, this study will present a conceptual framework to better understand the various ways in which students respond to each type of instruction. Specifically, I interpret student response as having three different constructs – cognitive, emotional, and behavioral (discussed further in Chapter 2) – and use these constructs to discuss the distinctive ways in which students might respond to each of these types of instruction. Similarly, this framework has led to the development and improvement of the quantitative instrument used in this study, which is something that can be used by instructors to gauge student response to the types of instruction they use in their own classrooms.

Finally, this study will serve as an example for how to use a mixed methods approach to research in engineering education, establishing what Creamer (2018) refers to as "methodological integrity" by "integrating qualitative (open-ended, small sample) and quantitative (close-ended, large sample) data [to produce] stronger conclusions than can be achieved with a single method alone" (p. 527). By incorporating a mixed methods approach to data collection and analysis, this study will share how both elements of research (e.g., quantitative and qualitative) contribute to a broader understanding of how students respond to the different types of instruction they encounter in the engineering classroom and why they respond in the ways that they do.

Research Questions

This study seeks to explain the relationship between prior and current student response to various types of instruction, the frequency with which each type of instruction is used in engineering courses, and how students ultimately evaluate their courses and instructors. The following broader research questions guide this study:

1. What types of instruction are being used in introductory engineering courses at a large research university?
2. How do students respond to different kinds of instruction in these courses? How does their previous experience with different kinds of instruction influence their response to its use in their current course?
3. What relationships exist between prior response, current response, the frequency with which each type of instruction is used in the current course, and how students subsequently evaluate the course and instructor?

This research will produce important insights into how students respond to different types of activities in the engineering classroom. In Chapter 2, I review the literature on EBIP and present the student response framework I use in this research study. In Chapter 3, I discuss the research design of this project and explain how I measured the frequency with which each type of instruction was used in the engineering classroom, how students responded in their prior and current courses, and how they evaluated their course and instructor. In Chapter 4, I report the quantitative findings using the two surveys from this research study. In Chapter 5, I report the qualitative findings from student focus groups. Finally, in Chapter 6, I discuss the overall findings of this research study, using both quantitative and qualitative results, and provide broader implications from this research, as well as recommendations for future research.

Chapter 2: Literature Review

The role of EBIP in the college classroom has received considerable attention in the higher education literature over the past several years. Yet, for many faculty, the conceptualization of what these strategies entail and how they can be applied in the college classroom is vague. Furthermore, many faculty who are familiar with EBIP fear that the adoption of nontraditional teaching will result in widespread resistance and a disruption of classroom learning (Borrego et al., 2010; Dancy & Henderson, 2012; Finelli et al., 2014; Fraser et al., 2014; Froyd et al., 2013; Henderson & Dancy, 2007; Seidel & Tanner, 2013). However, these apprehensions have not been properly investigated to determine their merit. Investigating how students respond to different types of instruction, then, is key to helping faculty adopt new approaches.

The chapter describes the need for a better understanding of student response to the types of instruction encountered in the engineering classroom and how prior research can guide knowledge about this topic. First, I review the literature on the types of instruction often encountered in the engineering classroom. I also provide a working definition for EBIP, highlighting student response to these types of instruction as evidenced in prior research while introducing the framework for how I organize these practices in my research study. Then, I introduce research on the three types of engagement typically exhibited by students in the classroom (Fredricks, Blumenfeld, & Paris, 2004), including adding a fourth construct to this framework in order to measure students' evaluation of the course and instructor, and describe how this framework will guide my measurement of student response to different types of instruction.

Types of Instruction in the Classroom

The types of instruction an instructor may use can be described by two distinct categories: traditional and nontraditional teaching methods. Traditional teaching methods involve lecture-style components of classroom instruction where students passively receive information from a lecturer (Felder & Brent, 2009; Hake, 1998; Johnson & Dasgupta, 2005). These methods are defined by their lack of involvement of the student in the learning process; the student is only present to receive information directly from the instructor.

Nontraditional teaching methods, also referred to as "evidence-based instructional practices (EBIP)" or "research-based instructional strategies (RBIS)," involve a deviation from the traditional lecture. "Active learning" is one common nontraditional teaching method, which Bonwell and Eison (1991) define as "anything that 'involves students in doing things and thinking about the things they are doing" (p. 2). This involvement includes activities that incorporate more than just listening skills, require students to use higher order thinking skills, and encourage students to discover their own values and emotions. An example of a simple type of active learning is think-pair-share where students think about a problem or question individually, then form pairs to discuss with peers and come to a mutual answer, and are often asked to share these answers with the class.

Other types of common nontraditional teaching methods include collaborative and cooperative learning. "Collaborative learning" is often defined in terms of activities in which students are generally encouraged to work in groups towards a common goal (Smith & MacGregor, 1992). This type of instruction can range from the carefully structured to the loosely guided. On the more structured end of the continuum, “cooperative learning” is often defined as type of instruction where students work on similar tasks while still receiving individual grades for their performance (Millis & Cottell, 1998). In cooperative learning, students are still accountable for their own performance, but are encouraged to work together to practice social skills, which benefit them well beyond the classroom (Millis, 1994; Millis & Cottell, 1998). An example of this in the college classroom might be a project for which students are asked to work together in a group but are still graded individually based on their performance in the group. Other types of cooperative learning found in the classroom include problem-based learning/problem-centered instruction (students work in groups to design a solution to a problem in the field), writing groups, peer teaching, and discussion groups (Smith & MacGregor, 1992).

Categorizing these terms into instructional practices, Borrego and colleagues (2013) characterized the most commonly-used practices in the engineering classroom into eleven RBIS categories. These included instructional practices involving varying levels of student activity and ones in which students both worked individually and in groups. While not exhaustive, these practices (adapted in Table 1) present a broad overview of the types of EBIP used most often encountered in the engineering field.

Student Response to Different Types of Instruction

Findings from prior research on student responses to the use of EBIP in STEM have been mixed. On the one hand, several studies have shown that students react positively to the use of EBIP in the classroom. For example, some research has indicated that students feel that the use of EBIP generally promotes student learning (Arce, 1994; Carlson & Winquist, 2011; Luckie, Maleszewski, Loznak, & Krha, 2004; Oakley, Hanna, Kuzmyn, & Felder, 2007; O’Brocta & Swigart, 2013; Wilke, 2003). Additionally, student satisfaction with each course has typically increased with the use of these practices (Armbruster, Patel, Johnson, & Weiss, 2009; Hall, Waitz, Brodeu, Soderholm, & Nasr, 2002; Hoffman, 2001; Richardson & Birge, 1995). The use of EBIP has also resulted in higher scores on examinations of student knowledge, as demonstrated by comparison with control groups using traditional pedagogical strategies (i.e., lecture; Armbruster et al., 2009; Conway, 2014; Hoffman, 2001; Mohamed, 2008; Reddy, 2000).

Table 1.
Most Commonly-Used EBIP in Engineering Ordered by Least to Most Difficult in Implementation[a] (adapted from Borrego et al., 2013)

Instructional Practice	Description
Think-pair-share	Students think about a problem or question individually, then form pairs to discuss with peers and come to a mutual answer, and are often asked to share these answers with the class.
Peer instruction	Instructor poses a question to the class and shares students' responses (often using "clickers") to generate conversation and discussion about the answer.
Concept tests	Instructor presents a multiple-choice question with common misconceptions for answers alongside the correct response.
Just-in-time teaching	Students complete a homework assignment or quiz before class, and the instructor adjusts the lesson based on students' responses.
Cooperative learning	Students work on similar tasks while still receiving individual grades for their performance.
Collaborative learning	Students work in groups towards a common goal.
Inquiry learning	Instructor begins the lesson by offering a question or problem that will guide students' thinking about the topic.
Problem-based learning	Student form self-directed teams to solve open-ended or ill-structured problems based on the course materials.
Think-aloud-paired problem solving	Students form pairs in which one student solves the problem while the other offers questions to clarify the thinking process.
Case-based teaching	Students analyze case studies of historical or fictional scenarios that involve problem solving and decision-making processes.
Service learning	Community service projects are incorporated into the course to provide experiential learning opportunities for real-world issues discussed in the course.

[a] Order of difficulty is adapted from the Center for Research on Learning and Teaching (CRLT) at the University of Michigan (http://crlt.umich.edu/active_learning_implementing)

On the other hand, not all student responses to the use of EBIP are positive. Despite empirical evidence that points to improved course grades and learning outcomes, many students do not feel that the use of these practices in the classroom benefits them over traditional lecture methods (Lake, 2001; Wilke, 2003; Phipps, Phipps, Kask, & Higgins, 2001; Yadav, Subedi, Lundeberg, & Bunting, 2011; Yadav, Vinh, Shaver, Meckl, & Firebaugh, 2014). For example, Yadav and colleagues found in two separate studies that while students' learning gains were greater in problem-based learning and case-based instructional classrooms when compared to those who participated in a traditional classroom, students believed they learned more from the traditional lecture (Yadav et al., 2011, 2014). These same results were found in studies looking at student motivation (Wilke, 2003; Phipps et al., 2001) and course evaluations (Lake, 2001). Although learning outcomes improved, students showed no differences in motivation when compared to those in traditional classrooms, and they often gave lower course ratings to instructors using EBIP.

Prior studies have indicated that the discrepancy between an instructor's use of EBIP and student response could be a result of students' dissatisfaction with a new type of instruction. For example, Trees and Jackson (2007) found in an experiment introducing student response systems (e.g., clickers) into the classroom that students felt negatively towards the use of this technology when its addition did not result in any perceived change in the classroom experience. When referencing group work and working on project teams with peers, Oakley et al. (2007) suggested that learning benefits and student satisfaction with the use of student teams could be directly attributed to how well an instructor organizes a group activity. Furthermore, Bacon, Stewart, and Silver (1999) found a negative relationship between peer evaluations and students' team experiences and a positive relationship between students' self-selection of team members and team experiences. In other words, students felt positively about group experiences if they were able to select their own teammates, but negatively if peer evaluations were used during the group process. This might also explain the mixed results from other studies in which the relationship between group work and student satisfaction was not explicitly measured (e.g., Yadav et al., 2011, 2014).

The discrepancies in these attitudes could also be a result of students' initial reluctance to participate in a new type of instruction. Van Barneveld and Strobel (2012) found that faculty in their study believed students' reluctance to participate in problem-based learning activities was a result of a lack of preparedness from their prior schooling (especially for those students coming directly from high school) and the transition to a new learning environment where they were more involved in the learning process. However, first-year students transitioning to a new learning environment might not be the only ones who express these feelings. Welsh (2012) found that fourth- and fifth-year students in science fields were more likely to view EBIP as waste of time and money, whereas third-year students found these practices to be influential in their learning process. Other studies have found discrepancies across gender, with female students more likely to feel that they benefit from EBIP when compared to their male peers (Welsh, 2012) and academic ability, with students having average or below average scores benefitting more than their higher scoring peers (Kvam, 2000).

In summary, prior research studies have produced mixed conclusions regarding the relationship between different types of instruction encountered in the classroom and student response, and more work is needed to better understand how and why different students respond in different ways. It is important to investigate whether the type of activity (e.g., group work, individual problem-solving, problem-based learning) and a student's previous experience with the type of activity also impacts student response.

The Interactive-Constructive-Active-Passive (ICAP) Framework

Understanding and observing student response to different types of instruction requires characterizing the type of instruction occurring, and the Interactive-Constructive-Active-Passive (ICAP) framework is one way to model that instruction. Chi and Wylie (2014) developed the ICAP framework as a way to categorize the "different modes or categories of 'active learning,' corresponding to different overt behaviors that elicit different knowledge-change or learning processes" (p. 220). In other words, passive modes of learning depict the lowest level of participation, followed by active, constructive, and interactive modes (Chi, 2009). The benefit of grounding the ICAP framework in observable student behaviors is that one can determine whether or not the student is engaged in the activity based upon simple examination of the classroom (Chi & Wylie, 2014). For example, if students have been asked to work in groups to solve a problem presented to them, the instructor can see whether or not a student is participating with other classmates in the process (at least at face value). I introduce these categories in reverse order from the order in which they appear in the acronym (PACI rather than ICAP) to highlight the increasing levels of student participation that should result when moving from the passive (lowest) to the interactive (highest) approach.

Passive. The lowest level of student participation in the ICAP framework, *passive*, encompasses all types of instruction in which students are merely inactive observers in the learning process. For these types of instruction, the student does little but receive information from the instructor on the topic. This type of learning can also include taking notes on the lecture, but only if the student is transcribing notes from the instructor verbatim. If the student chooses to reconstruct the material in her or his own words, this would be considered a *constructive* type of activity (Chi & Wylie, 2014).

Active. The *active* category encompasses those types of instruction in which the learner makes some effort during the participation process. The effort could be physical (e.g., inspecting a mechanical object to determine its functional properties) or mental (e.g., completing a problem set during class), but these types of instruction differ from *passive* ones in that the student is involved in the learning process beyond watching an instructor lecture or taking notes on a lecture topic in the instructor's own words (Chi & Wylie, 2014). These types of instruction also differ from *interactive* ones in that the learner is working as the sole agent in the learning process, and no group work is expected during the activity (Chi & Wylie, 2014). Examples of these types of instruction include solving a problem set individually and answering questions posed by an instructor during class (Alibali & DiRusso, 1999).

Constructive. The *constructive* category consists of those types of instruction in which students create new ideas based on what was provided to them by the instructor. For example, if students were asked to solve an ill-structured problem (i.e., a problem where incomplete information is provided and no perfect solution exists), they would have to generate a solution that was not explicitly given in a solution set for that problem (i.e., they would have to generate their own solution; Chi & Wylie, 2014). The *constructive* category differs from the *active* one in that students are not simply participating in an activity; they are generating new knowledge through their participation (Chi, Bassok, Lewis, Reimann, & Glaser, 1989). Examples of these types of activities include drawing concept/knowledge maps (Novak, 1990), integrating concepts across multiple sources of information (e.g., textbooks, research articles, multimedia; Bodemer, Ploetzner, Feuerlein, & Spada, 2004; Rouet, Britt, Mason, & Perfetti, 1996), and explaining concepts in one's own words (self-explaining; Chi et al., 1989).

Interactive. Chi and Wylie's (2014) *interactive* category is comprised of the types of interpersonal activities in which individuals engage with others during the process of knowledge construction. The authors note that interactive activities must meet two criteria. First, all individuals engaged in the activity must undergo the process of the constructing behavior with the other(s) in the group. For example, if neither student in a pair presents additional knowledge beyond what was provided by the instructor, this would not fall under Chi and Wylie's (2014) classification of *interactive.* Second, the depth of interaction between individuals in the group should be balanced and somewhat substantial. This means that individuals should have ample opportunity to engage with one another during the activity, rather than a casual interaction such as quickly sharing what each arrived at as the answer to a question. Examples of these types of activities include explaining a topic or problem to one another in their own words (Roscoe & Chi, 2007), critically responding to one another's contributions to the activity (Okada & Simon, 1997; Schwarz, Neuman, & Biezuner, 2000) and building upon on another's contributions to create a group response to a problem or question (Hogan, Nastasi, & Pressley, 1999).

Student Response Framework

Though the type of instruction can be characterized according to the level of participation an instructor expects the students to have, the actual level of engagement (e.g., whether or not the student actually participates) and the reason for this engagement (e.g., investment in their own learning, establish an emotional connection to the course or instructor) can vary considerably (Pekrun & Linnebrink-Garcia, 2012). For example, during an individual problem-solving activity, the range of student engagement could vary from highly engaged (the student is completing the problem set and asking the instructor questions) to not engaged at all (the student chooses to work on a task from another class). Student engagement is a malleable trait of the individual interacting with his or her learning environment, and it is subject to change based upon the changes in the individual and the learning environment over time (Connell, 1990; Finn & Rock, 1997; Fredricks et al., 2004).

Students' engagement with individual courses and their overall engagement in the campus environment are crucial factors in their success, especially at the postsecondary level. Student engagement has been found to have positive relationships with classroom and institutional learning goals and achievement (Carini, Kuh, & Klein 2006; Coates 2007; Park

2005), persistence and retention (Carini et al., 2006; Tinto, 2006), and socialization and overall life satisfaction (Lewis, Huebner, Malone, & Valois, 2011; Li, Lerner, & Lerner, 2010; Trowler & Trowler, 2010).

Researchers have identified two components of student engagement at the university level – campus and class engagement – to attempt to explain how students interact in academic and social settings, respectively (Gunac & Kuzu, 2014). These relationships, illustrated in Figure 2, complement theories on student departure and retention in college, which have indicated that both social (campus) and academic (class) engagement are key to student success and remaining enrolled in college through graduation (Tinto, 1987, 1993).

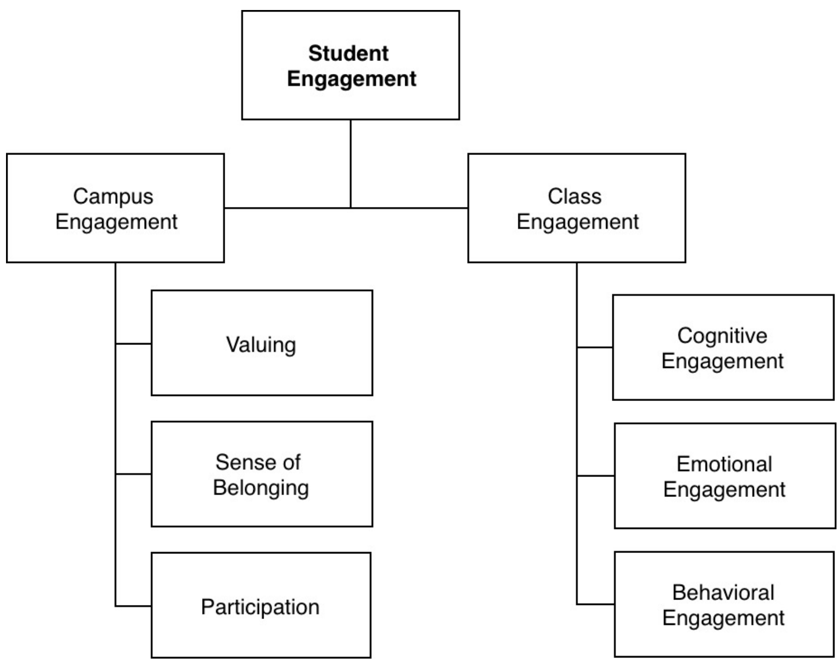

Figure 2. Student engagement and dimensions (Gunac & Kuzu, 2014).

While campus engagement is a critical piece of students' overall engagement with an institution, it is beyond the scope of this dissertation study. Therefore, I focus on "class engagement" as defined by Gunac and Kuzu (2014; right side of Figure 2). According to this definition, the three types of class engagement include cognitive (how students think), emotional (how students feel), and behavioral (how students act) components of engagement (Appleton, Christenson, Kim, & Reschly, 2006; Finn, Pannozzo, & Achilles, 2003; Fredricks et al., 2004; Furrer & Skinner, 2003; Helme & Clarke, 2001).

I modify this framework to include an additional component for how students respond to classroom engagement on student evaluations of teaching (Figure 3). Although these evaluations have less to do with how students think, feel, and act, they are often used as a "pulse" for student satisfaction with the course and instructor. Thus, how student think, feel, and act about a type of instruction could have a direct impact on how they respond to the course and instructor on these evaluations.

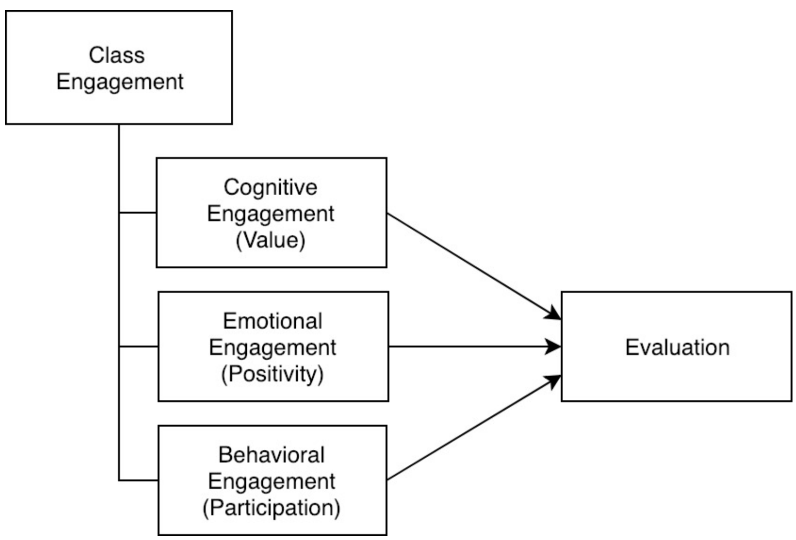

Figure 3. Modified class engagement framework with evaluation construct (adapted from Gunac & Kuzu, 2014)

Cognitive Engagement

Cognitive engagement encompasses students' interest in and understanding of their own learning process (i.e., how students think about the learning process; Fredricks et al., 2004). Research in this area is founded in the literature on school engagement and presents cognitive engagement as a student's investment in his or her learning and the desire to complete more than the necessary tasks assigned in an activity (Connell & Wellborn, 1991; Newmann, Wehlage, & Lamborn, 1992; Wehlage, Rutter, Smith, Lesko, & Fernandez, 1989). Some researchers have described this framework as including comfort in solving complex problems and a desire to work hard at assigned tasks (Connell & Wellborn, 1991), while others have represented it as including self-regulation, or an internal desire to complete a task to the best of one's ability regardless of external interests (Newmann et al., 1992).

Given that EBIP have been suggested to better prepare engineering graduates for the workforce (Crawley, Malmqvist, Ostlund, & Brodeur, 2007; NAE, 2004), it is important to investigate whether or not students perceive these types of activities as valuable. Thus, this research study focuses on the relationship between cognitive engagement and the "instrumental value" (i.e., the perception of how tasks or activities relate to future goals or everyday tasks) students place on the types of instruction they encounter (Blumenfeld et al., 2006). For this research study, I operationalize cognitive engagement within the classroom as the *value* that a student places on the types of instruction he or she encounters in a course.

Emotional Engagement

Emotional engagement refers to a student's emotional connection to faculty/staff, his/her peers, and course content, including his/her attitudes and relationships with key actors in the learning process (i.e., how students feel about the learning process; Fredricks et al., 2004). Emotional engagement may also be defined as a student's identification with or sense of belonging to their school or learning environment (Finn, 1989; Voelkl, 1997). This dimension is grounded in research on student attitudes and includes feelings such as liking/disliking a teacher, a school, and/or a course, as well as happiness, sadness, anxiety, or boredom with the learning process (Epstein & McPartland, 1976; Yamamoto, Thomas, & Karns, 1969). Unfortunately, the source of emotional engagement or interest is often unclear, as the reaction could be the result of either situational or personal interest.

Situational interest can vary based on specific features of an activity, such as interacting with an instructor for the first time, while personal interest is much more consistent across contexts and is based on an individual's preferences (Krapp, Hidi, & Renninger, 1992). For example, if a student is anxious about an instructor asking her/him a question during class, the anxiety could stem from having not met the instructor before and wanting to make a good impression (situational interest), or it could stem from a general dislike of interacting in a question/answer format with an instructor (personal interest/preference). As such, it may be difficult to tell whether the reaction is centered on the situation, peers, course content, or the instructor (Fredricks et al., 2004). However, for this study, I focus my efforts on emotional engagement through the study of a student's *positivity* towards the types of instruction used in the course and, subsequently, his/her *positivity* towards the instructor for using these types of instruction.

Behavioral Engagement

Behavioral engagement often refers to if and how a student participates in classroom activities (i.e., how students act during the learning process). Definitions of behavioral engagement are often extended to include whether the student participates in this or other school-related activities (Finn, 1993; Finn, Pannozzo, & Voelkl, 1995), whether or not the student puts effort into participating in classroom activities (Birch & Ladd, 1997; Finn et al.,1995; Skinner & Belmont, 1993), and how a student behaves in the classroom (e.g., whether the student exhibits positive conduct by following classroom norms or negative conduct by disrupting the learning process; Finn, 1993; Finn et al., 1995; Finn & Rock, 1997).

Students may resist certain types of instruction (particularly those that feature EBIP) for several reasons, including the amount of work involved in the practice, the novelty of the experience, and the level of discomfort experienced when participating in a new activity (Weimer, 2013). Kearney and Plax (1992) identified 19 of the most common techniques that students use when exhibiting resistance, which Weimer (2013) classified into three categories:

1. *Passive, non-verbal resistance* is a type of resistance where students exhibit an "overwhelming lack of enthusiasm" (Weimer, 2013, p. 205). The student might not verbally express their lack of engagement, but they will not participate in the activity. Common resistance techniques in this category include faking attention, appearing to take notes while working on material from another class, or refusing to participate.
2. *Partial compliance* is a type of resistance where the student will "resist by doing the task poorly, doing it halfheartedly, or doing it very, very quickly" (Weimer, 2013, p. 206). The student will participate in the activity, but often with very minimal effort. Common resistance techniques in this category include reluctant compliance, modeling instructor behavior/affect, and student rebuttal.
3. *Open resistance* is a type of resistance in which students openly object to the activity or the instructor's teaching methods. This might be done through arguing during or after class, or purposely disrupting others in the learning process, but the student makes it clear that they are exhibiting resistance. Common resistance techniques in this category include challenging the instructor's power, disruption, hostile defense, and revenge.

Thus, for this research study, I operationalize behavioral engagement within the classroom as how a student *participates* in classroom activities.

Evaluation

Student evaluations of teaching (hereafter just referred to as evaluations) were included in this student response framework for three reasons. First, despite the many criticisms leveled towards the biases inherent in these evaluations (e.g., gender, course size, grade expectations, and academic rank), these evaluations are still the most commonly-used method for evaluating teaching effectiveness in tenure and promotion decisions (Abrami, d'Apollonia, & Rosenfield, 2009; Benton & Cashin, 2012, 2014; Sojka, Gupta, & Deeter-Schmelz, 2002).

Second, given that the first point is true, faculty are naturally reluctant to implement new practices, particularly EBIP, in their classrooms because of the potential backlash from students on evaluations (Anderson & Finelli, 2014; Finelli et al., 2014; Kober, 2015; Seymour & Hewitt, 1997). Thus, knowing more about the relationship between student response and evaluations is important in helping faculty understand what to expect when students participate in various types of instruction.

Finally, prior research has already linked some elements of student response to evaluations. For example, several studies in education have already discovered a significant relationship between student attitudes and evaluations (Douglas & Carroll, 1987; Hofman & Kremer, 1980; Marsh, 1984, 1987; Tom, Swanson, Abbott, & Cajocum, 1990). Other research has found that if students have negative attitudes towards their exams or activities throughout the course, evaluation scores will significantly drop (Millea & Grimes, 2002). Despite these findings, however, few research studies have examined what instructional factors influence these attitudes and how they subsequently impact students' evaluations of an instructor or course. This is a clear strength of this research study.

Conceptual Framework: Student Response to Types of Instruction

Given that different types of instruction stimulate different learning processes, I hypothesize: 1) the type of instruction used in the classroom directly impacts the response of the student (e.g., value, positivity, and participation), and 2) a student's prior response to a type of instruction will impact the relationship between the subsequent use of that type of instruction and a students' evaluation of the course and instructor. My previous work with a research team that sought to characterize student response to EBIP has identified practices an instructor can use to reduce resistance. However, that research has not measured students' responses to specific types of instruction, nor has it included an analysis of the role of students' prior experiences. Studying both of these parameters may allow us to better understand how the demands of certain types of instruction (e.g., interactive vs. active vs. constructive vs. passive) impact students' engagement and how prior response to their experiences with these types of instruction might impact future behavior.

Figure 1 in Chapter 1 depicted a simplistic conceptualization of these relationships. In Figure 4, the student response boxes are expanded as according to Gunac and Kuzu's (2014) concepts of class engagement and Fredricks et al.'s (2004) concepts of cognitive, emotional, and behavioral responses. This figure illustrates how this framework applies to each type of instruction, although the strength of each relationship may differ with each type of instruction. As indicated in Figure 1 and depicted again with the arrows in Figure 4, I predict that there is a relationship between students' prior and current response to each type of instruction, the frequency with which each type of instruction is used in the course, and students' subsequent evaluation of the course and instructor. This conceptual framework serves as the template for the design of this research study as discussed further in the next chapter.

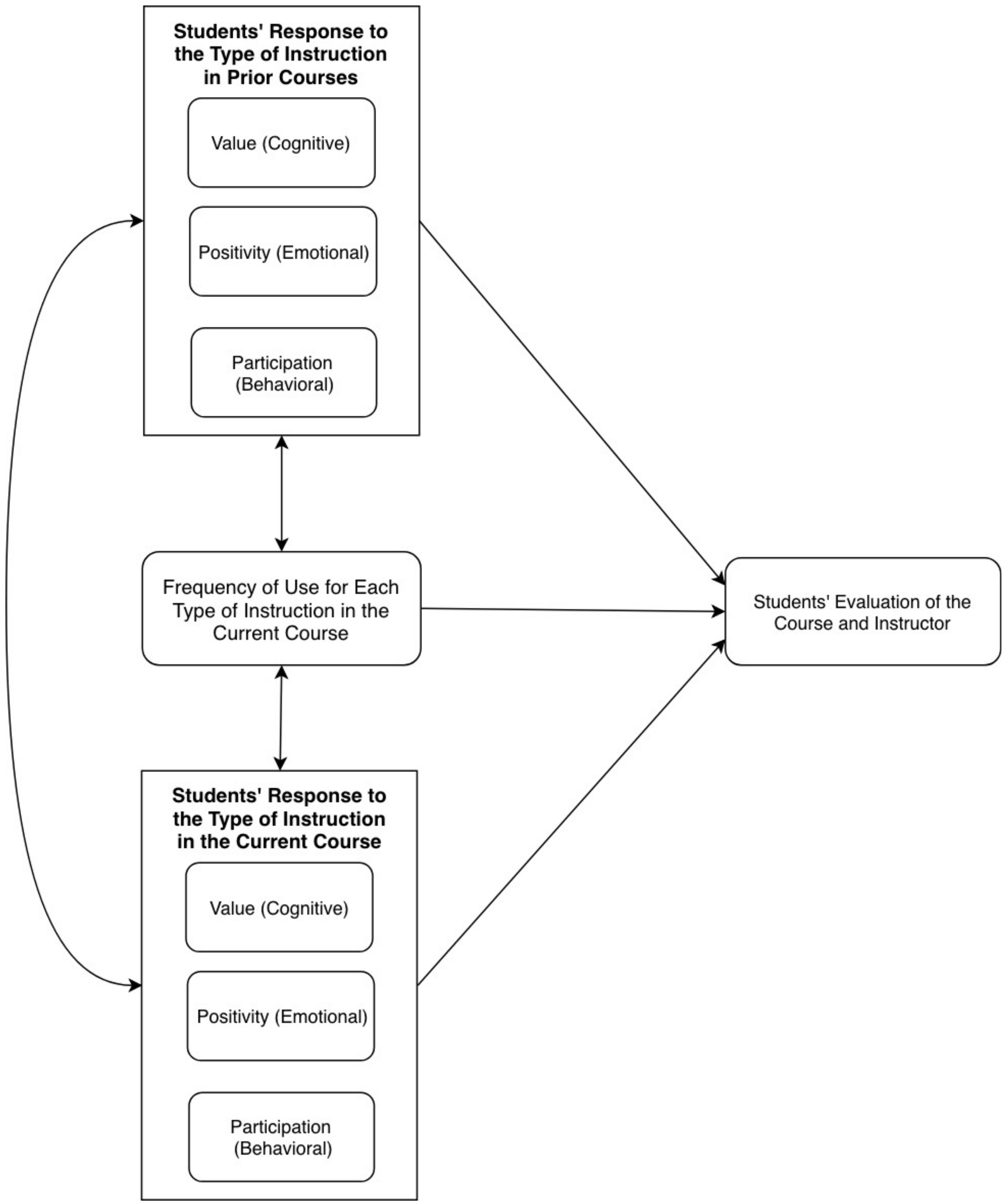

Figure 4. Expanded framework for the relationship between type of instruction (including students' prior experiences with the type of instruction) and student response.

Chapter 3: Methodology

In this study, I investigate the relationship between student response and the types of instruction used in the engineering classroom. More specifically, I use the ICAP framework to explore how student response (cognitive, emotional, and behavioral) differs according to the type of instruction. These considerations allow me to address my research questions:

1. What types of instruction are being used in introductory engineering courses at a large research university?
2. How do students respond to different kinds of instruction in these courses? How does their previous experience with different kinds of instruction influence their response to its use in their current course?
3. What relationships exist between prior response, current response, the frequency with which each type of instruction is used in the current course, and how students subsequently evaluate the course and instructor?

In this chapter, I first describe the study design and research participants, including the research site, the methods used to select the sample, and the characteristics of the participants. Next, I discuss the measures used for this research, including the design of the survey instruments and focus group protocol, as well as when the data for each of these measures were collected. Then, I discuss the analytic sample for my analysis, including demographic characteristics of the participants in this study. Finally, I discuss the methods of analysis that I use to answer my research questions.

Study Design

To answer the research questions in this study, I employed a mixed methods approach to data collection, analysis, and integration of quantitative and qualitative data throughout the research process (Creswell, 2005; Teddlie & Tashakkori, 2009). Researchers often use a mixed-methods design when neither quantitative nor qualitative methods are satisfactory in attempting to address the phenomena under study (Creswell, 2005). For this study, I asked both the ways in which students respond to the types of instruction in their classrooms (through quantitative surveys) and why students respond in these various ways (through qualitative focus groups). For example, students may indicate a more positive response for passive types of instruction over active types, but only asking how they responded leaves questions regarding why they see one type of instruction in a more positive light than others. When used in combination, quantitative and qualitative research methods complement one another and provide a greater understanding of the research question (Green, Caracelli, & Graham, 1989; Johnson & Turner, 2003; Teddlie & Tashakkori, 2009).

In this study, I used a concurrent nested design for mixed methods analysis (Creswell, 2005), which consists of the simultaneous collection of quantitative and qualitative data on the same research questions separately. During the analysis phase, however, a nested design has a predominant method that guides the analysis, while the other concurrent element is embedded to help address a different research questions or offer additional information on the research question not provided both the dominant method (Creswell et al., 2003). In this study, I collected data from survey instruments (quantitative) and focus groups (qualitative) during similar time periods; however, the quantitative results help to address the ways in which students respond to these various types of instruction encountered in the engineering classroom, while the qualitative results uncover why students respond in these various ways. I then brought these two data sources together in the discussion section (Chapter 6) to provide a holistic review of student response to these types of instruction.

Research Participants

As discussed in the introduction, in response to recent calls to improve the quality of undergraduate teaching and recent calls to use active learning to increase student learning and retention, I investigate the types of instruction used in gateway engineering courses at the University of Michigan in six engineering specialties: electrical engineering, computer science engineering, chemical engineering, mechanical engineering, materials science and engineering, and biomedical engineering. These six disciplines enrolled 77% of all undergraduate students who had declared their major in the College of Engineering at the University of Michigan for 2015-2016. The only other engineering discipline with a significant number of declared students was industrial and operations engineering (12% of all declared students); however, because this department's gateway course used a split-semester design (one course/instructor in the first seven weeks of the semester and a separate course/instructor in the last seven weeks of the semester), I did not select this discipline for my study. In addition, the gateway courses for the selected disciplines enroll large numbers of students each semester. For example, across the available gateway courses, the average class capacity is 104 students, with only three courses having a class capacity of fewer than 50 students.

From the Winter 2017 course offerings, I randomly selected one course section from each of the six engineering disciplines. The selection pool included sophomore-level courses (i.e., 200-level courses) with minimum enrollments of at least 50 students (the exception is CHE 330 and 341, which are 300-level courses, but the first courses offered in the chemical engineering discipline). While these courses differ by discipline, all are similar in that they are lecture sections of the course (i.e., no laboratory or discussion sections), they are one of the first courses taken in the disciplinary sequence (i.e., a sophomore-level gateway course), they typically enroll only students of sophomore status (after students have declared their major), and they enroll a large number of students. I randomly selected one course from each discipline and invited the instructor to have his or her course participate in the research study. If an invited instructor was unwilling or unable to participate, I randomly selected another course from the list in the same discipline. All instructors of gateway courses in Materials Sciences and Engineering (three courses available) opted out of participating, so the sample of selected courses only includes the disciplines of Biomedical Engineering (BME), Chemical Engineering (CHE), Electrical Engineering (ECE), Computer Science Engineering (CSE), and Mechanical Engineering (ME). Table 2 presents an overview of the sampled courses. Each section had enrollments of between 73 and 148 students, with an average enrollment of 108 students. The total population sampled was 539 students. No students were enrolled in more than one of these courses during the survey administration.

Table 2
Courses Selected for this Research Study

Course Label	Department	Course	Course Name	Number of Enrolled Students
BME	BIOMEDE	231	Intro to Biomechanics	96
CHE	CHE	330	Thermodynamics	143
ECE	EECS/ECE	215	Intro to Electrical Circuits	73
CSE	EECS/CSE	280	Programming & Data Structures	148
ME	MECHENG	211	Intro to Solid Mechanics	79

Quantitative Measures

I employed a series of two student surveys (hereafter named Surveys 1 and 2), which were based on the Student Response to Instructional Practices instrument (StRIP instrument;

DeMonbrun et al., 2017). I first discuss the original StRIP instrument, and then the adaptation of this instrument for the purposes of this research study.

The StRIP Instrument

To address gaps in the literature in understanding relationships between types of instruction, student response, and the strategies utilized often to overcome resistance to EBIP, I worked with a research team to design the StRIP Instrument, which we used to examine student response to types of instruction in a variety of introductory engineering courses across the United States (DeMonbrun et al., 2017; Nguyen et al., 2017a). Among other things, the StRIP Instrument includes sections that measure types of instruction and student responses to instruction.

Types of instruction. We included 21 “types of instruction” items (Table 3) in the StRIP Instrument, in alignment with Chi and Wylie’s (2014) ICAP model (see Chapter 2 for an overview of this model). After we performed an exploratory factor analysis to establish factors for these 21 items, we established a four-factor structure. Although the ICAP nomenclature, as originally defined, does not exactly capture the essence of these resulting factors, we chose to keep these titles for convenience as these titles characterize the type of participation that each type of instruction is expected to elicit. As noted in Chapter 2 of this dissertation, these categories are presented in reverse order from the order in which they appear in the acronym (PACI rather than ICAP) to highlight the increasing levels of student participation. These four factors include:

- Passive: Instruction where students are expected to passively receive information from the instructor through lecture.
- Active: Instruction where students are engaged in content through an individual activity.

- Constructive: Instruction where students are expected to learn through self-discovery, rather than by being told what to do by the instructor.
- Interactive: Instruction where students are engaged in content through working in groups with one or more peers.

Table 3
"Types of Instruction" Items

For each of the following types of instruction, please indicate how often you have done this so far in this course.

1. Almost never (<10% of the time); 2. Seldom (~30% of the time); 3. Sometimes (~50% of the time); 4. Often (~70% of the time); 5. Very often (>90% of the time)

Passive	1. Listen to the instructor lecture during class. 2. Watch the instructor demonstrate how to solve problems. 3. Get most of the information needed to solve the homework directly from the instructor.
Active	4. Make individual presentations to the class. 5. Be graded on my class participation. 6. Solve problems individually during class. 7. Answer questions posed by the instructor during class. 8. Ask the instructor questions during class. 9. Preview concepts before class by reading, watching videos, etc.
Constructive	10. Make and justify assumptions when not enough information is provided. 11. Find additional information not provided by the instructor to complete assignment. 12. Take initiative for identifying what I need to know. 13. Brainstorm different possible solutions to a given problem. 14. Assume responsibility for learning material on my own. 15. Solve problems that have more than one correct answer.
Interactive	16. Solve problems in a group during class. 17. Do hands-on group activities during class. 18. Discuss concepts with classmates during class. 19. Work in assigned groups to complete homework or other projects. 20. Be graded based on the performance of my group. 21. Study course content with classmates outside of class.

Student responses to types of instruction. Drawing upon Fredricks et al.'s (2004) classroom engagement concept and Weimer's (2013) student resistance framework, we included 13 items to assess the three types of student engagement (cognitive, emotional, and behavioral). Then, because of the importance of end-of-semester student teaching evaluations in faculty decisions to adopt EBIP (Finelli et al., 2014; Remington et al., 2015; Stead, 2005), we added three items to assess students' evaluations of the course/instructor.

Altogether, this section of the StRIP instrument includes 16 items (see Table 4), categorized into the following four constructs:

Table 4
"Students' Responses to Instruction" Items

For your prior course, did the instructor ever ask you to [discuss concepts with classmates during class/brainstorm different possible solutions to a given problem/answer questions posed by the instructor during class/listen to the instructor lecture during class]? 1. Yes 2. No		
(If yes) In this course, when the instructor asked you to participate in this type of instruction, how often did you react in the following ways? *1. Almost never (<10% of the time); 2. Seldom (~30% of the time); 3. Sometimes (~50% of the time); 4. Often (~70% of the time); 5. Very often (>90% of the time)*		
Value	1.	I felt the effort it took to do the activities was worthwhile.
	2.	I saw the value in the activities.
	3.	I felt the time used for the activities was beneficial.
Positivity	4.	I disliked the activities. (R)
	5.	I felt positively towards the instructor because of the activities.
	6.	I enjoyed the activities.
	7.	I complained to other students about the activities. (R)
Participation	8.	I tried my hardest to do a good job with the activities.
	9.	I did not actually participate in the activities. (R)
	10.	I gave the activities minimal effort. (R)
	11.	I distracted my peers during the activities. (R)
	12.	I pretended to participate in the activities. (R)
	13.	I surfed the internet, checked social media, or did something else instead of doing the activities. (R)
Evaluation (not used in Survey 1)	14.	Overall, this was an excellent course.
	15.	Overall, the instructor was an excellent teacher.
	16.	I would recommend this instructor to other students.

(R) These items were reverse-coded.

- Value (cognitive engagement) – Three questions were selected to measure the type of psychological investment students put into the type of instruction, or specifically, the instrumental value they place on the type of instruction being used.
- Positivity (emotional engagement) – Four questions were selected to measure how positively (or negatively) students feel about their social/emotional connection to the type of instruction and the instructor who facilitates the type of instruction.
- Participation (behavioral engagement) – Three questions were selected to measure the degree to which students choose to or choose not to participate in a type of instruction.
- Evaluation – Three questions were selected to measure how students rate the course and instructor on end-of-semester evaluations of teaching.

Validity and reliability of the StRIP instrument. The StRIP instrument was constructed and tested for validity and reliability of its measures in a variety of ways (DeMonbrun et al., 2017; Nguyen et al., 2017a). First, we used observational studies of active learning practices in a sample of engineering classrooms to confirm the accuracy of the instrument (i.e., it correctly captured the types of instruction encountered in the classroom and student response to these types of instruction). Second, we subjected the instrument to multiple iterations of review by an advisory board of experts who were experienced in instrument design and psychometrics, types of instruction, and students' responses to different types of instruction. Finally, after developing the final instrument, we conducted cognitive interviews (Willis, 2004) with undergraduate engineering students to confirm that this instrument was well constructed for the target audience (i.e., undergraduate engineers).

After the initial survey design process, we sampled a total of 362 students in eight courses at four institutions and used data from this pilot testing to conduct exploratory and confirmatory factor analyses. Each of the factors for the types of instruction and response had construct reliabilities above 0.70, and all items had loadings well above the 0.32 threshold (Comrey & Lee, 1992). The factor loadings for the StRIP instrument are provided in Appendix A. The factor loadings for the revised instruments in this study (Surveys 1 and 2) are provided in the quantitative results section in Chapter 4.

Surveys 1 and 2

To address the present research questions, I refined the StRIP instrument in two ways. First, I included a series of items related to students' prior experience with different types of EBIP. Second, to overcome a limitation of the StRIP instrument, which was that it asked students to indicate how they typically responded to an in-class activity without specifying the exact activity, I included a series of items asking students to indicate how they typically respond to a number of in-class activities. To reduce survey fatigue (asking 13 response questions for each of the 21 types of instruction), I chose the most commonly-used type of instruction – as indicated in our original research (DeMonbrun et al., 2017) – in each of the four categories of ICAP. In other words, I ask the 13 response questions for the four commonly-used types of instruction (one in each ICAP category). These types of instruction, and the shorthand used to describe each one throughout the rest of this study, include:

- Listen: "Listen to the instructor lecture during class" (passive),
- Answer Q's: "Answer questions posed by the instructor during class" (active),
- Brainstorm: "Brainstorm different possible solutions to a given problem" or (constructive), and
- Discuss: "Discuss concepts with classmates during class" (interactive).

Overall, I designed two surveys to measure students' response to each individual type of instruction that occurred most commonly in the classroom and to gauge students' prior experiences with each type of instruction. Survey 1, administered between the fifth and seventh weeks in the course, was designed to collect demographic information and to assess students' prior experience with EBIP. Survey 2, administered between the thirteenth and fifteenth weeks in the course, was designed to collect information about students' attendance and grades in the course and to measure how students responded to the most commonly-used types of instruction in their current courses. An illustration of the data collection timeline, which includes the timing for focus groups that I discuss in a later section, is presented in Figure 5. The list of questions from Surveys 1 and 2 are provided in Appendices B and C, respectively.

Figure 5. Data Collection Timeline.

Survey 1. Survey 1 contains three types of measures: (1) socio-demographic questions, (2) types of instruction encountered during the first five weeks of the current course, and (3) student responses to four commonly-used types of instruction in a prior course. Socio-demographic questions (Table 5) include year in college (first-year, second-year, etc.), gender, race/ethnicity, citizenship status, current GPA, and current/intended major. Students were given the opportunity to opt out of providing this information, in accordance with specifications from the institutional review board.

The section on types of instruction includes 21 types of instruction in engineering courses (Borrego et al., 2013), which fit into each of the four ICAP classifications. These items are indicated in Table 3. The section on student response to types of instruction in a prior course (Table 4) begins by asking students to consider the engineering course they took in the previous semester (Fall 2016) that is the most relevant to their current course and to indicate their prior experience with four of the most commonly-used types of instruction in engineering courses (one type of instruction for each of the ICAP categories).[1] If a student had been exposed to this type of instruction in the prior course, s/he is also asked how s/he typically responded to it using the three classroom engagement constructs of value, positivity, and participation. Since this survey measured experiences in a prior course, end-of-semester evaluation questions are not asked in Survey 1.

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[1] These types of instruction were identified using data from the pilot study of the instrument (DeMonbrun et al., 2017).

Table 5
Socio-Demographic Questions

Demographics/Goals	
Year in College	**What is your current/intended major?**
First	Aerospace Engineering
Second	Biomedical Engineering
Third	Chemical Engineering
Fourth	Civil Engineering
Gender	Climate and Meteorology
Female	Computer Engineering
Male	Computer Science
Race/Ethnicity	Data Science
White	Electrical Engineering
African American	Engineering Physics
American Indian/Alaska Native	Environmental Engineering
Asian-Pacific Islander	Industrial and Operations Engineering
Latino/a	Materials Science and Engineering
Multiracial	Mechanical Engineering
Citizenship Status	Naval Architecture and Marine Engineering
U.S. Citizen	Non-Engineering
Permanent Resident (green card)	Nuclear Engineering and Radiological Sciences
International Student (F-1, J-1, M-1, or other visa)	Space Science and Engineering
What is your current GPA?	
3.5 or higher	
3.0 to 3.49	
2.5 to 2.99	
2.0 to 2.49	
0 to 1.99	

Survey 2. Survey 2 contains three types of measures: (1) course-related questions, (2) student responses to the most commonly-used types of instruction (the same four types of instruction queried in Survey 1) in the current course, and (3) end-of-semester evaluations of the current course. Course-related questions (Table 6) include questions about students' expected grades in the course and about how frequently they attended lecture during this semester.

The section on student response to types of instruction asks students about their response (using questions from Table 4) to the same four types of instruction as indicated in Survey 1, but it differs in asking these items in regards to the course in which the student was currently enrolled. Finally, students are asked about their response to three common questions on the end-of-semester student evaluations of teaching (also presented in Table 4).

Table 6
Course-Related Questions

Questions	
What is your expected grade in the course? A+/A- B+/B- C+/C- D or below	**About how frequently did you attend lecture this semester?** Always (100% of the time) Most of the time (75% of the time) About half the time (50% of the time) Sometimes (25% of the time) Never

Focus Groups

In addition to administering Surveys 1 and 2, I conducted student focus groups to provide additional context regarding experiences with each type of instruction in their currently enrolled course. I invited all students who completed Survey 1 to participate in a 60- to 75-minute focus group. I structured the focus groups to elicit (1) information relevant to students' experiences participating in each type of instruction in the course, and (2) students' experiences with each of these types of instruction, including how their experiences may impact subsequent reactions to each type of instruction in the current course. For the second half of the focus group, I distributed an example of how these experiences might impact future responses to types of instruction (Figure 6) as a way to get students to discuss these concepts and whether or not they agreed with this framework. Table 7 shows the semi-structured protocol I used to guide the focus groups. I conducted (and audio-recorded) a total of five focus groups. The focus groups featured a mix of students from multiple courses, which allowed them to share similar and contrasting experiences.

Analytic Sample

The sample used in the results section of this study included 242 students who completed both Survey 1 and 2. All 242 students indicated that they had experienced some form of the four most common types of instruction (by ICAP designation) in a previous course, and thus provided answers to the prior student response items in Survey 1. From the original targeted sample of 539 students in each of the five courses in this study, approximately 45% of all solicited students completed both Survey 1 and 2. Response rates for each individual course were as follows: BME – 66%; CHE – 29%; ECE – 40%; CSE – 51%; ME – 42%. As indicated earlier, no students were enrolled in more than one of the five selected courses, and therefore, no student responded to more than one set of surveys.

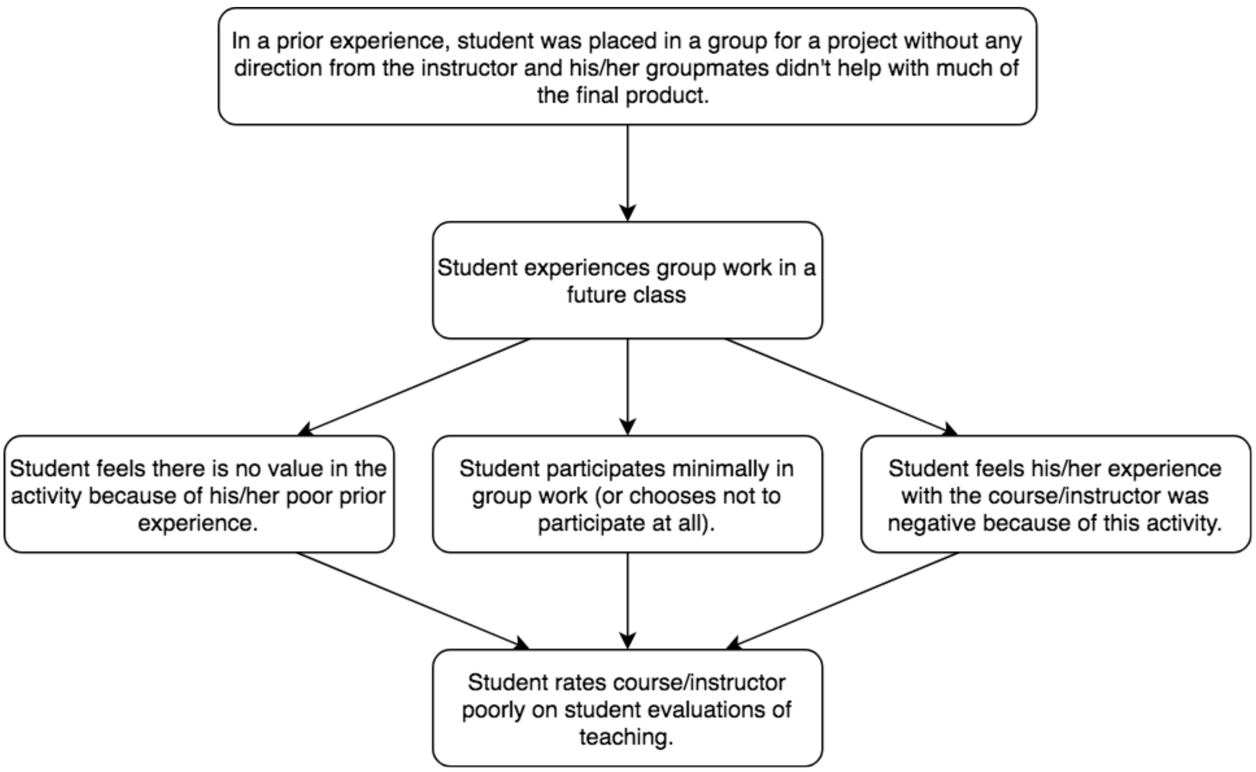

Figure 6. Example of model for types of instruction, prior experiences, and student response provided to students in focus groups.

The socio-demographic characteristics of students who completed both surveys, including year in college, gender, race/ethnicity, citizenship status, current GPA, and current/intended major are presented in the left-hand column of Table 8. I also included the course-related questions about students' expected grades in the course and about how frequently they attended lecture this semester. Given that this is not a random sample of students in the five targeted courses in this study, I have also provided the demographics for the total population of these courses in the right-hand column of Table 8, with the exception of the course-related questions that were self-reported by the sample population only.

Table 7
Semi-Structured Protocol for Focus Groups in the Research Study

Here are some types of instruction that you and your colleagues have reported are used most often in your engineering courses. Thinking about the course you're currently enrolled in (BIOMEDE 231, CHE 330, EECS 215, EECS 280, or MECHENG 211), which of these activities have you experienced in this course?

(For each type of instruction mentioned by students, probe for prior experiences with each of these types of instruction)

- Can you give me an example of how this type of instruction was used in your current course?
- How many have encountered this type of instruction in prior courses?
    - For those who have, do you think your experience in prior courses influenced how you responded to this type of instruction this semester?
        - If so, why do you think this influenced your response?
        - If not, why do you think this didn't influence your response? Was there something different about this experience from your prior experiences?
- How many had not encountered this type of instruction in prior courses?
    - For those who have not experienced this type of instruction before, how did you generally feel about it the first time you experienced it?
        - For example, did you see the value in participating in the activity? Did your participation in this type of instruction make you feel more positively about/connected to the course or instructor? Did it make you more/less likely to participate or not?
    - Why did you feel that way?
    - Do you think your feelings about this experience (value, positivity, participation/resistance, etc.) will affect how you approach this type of instruction in the future? Explain why or why not.
- How many of you enjoyed participating in this type of instruction in your course?
    - For those who enjoyed it, how did this influence your participation in the course?
        - Did this encourage you to become more involved in other types of instruction your instructor used?
    - For those who didn't enjoy it, why was this experience not enjoyable for you?
    - (If not discussed with lack of enjoyment) Have any of you had a negative experience with this type of instruction in the past?
        - If so, do you feel this affected how you responded to this type of instruction this semester?
        - Did the experience this semester with the type of instruction change your feelings (value, positivity, participation/resistance, etc.) about it? Why or why not?

In this study, I've been looking at how students' prior experiences with a type of instruction generally affects their response to the use of the same type of instruction in subsequent courses. This worksheet represents how I think this relationship works. (Walk through worksheet with students.)

- What are your thoughts about this model?
- Do you feel your prior experience with a type of instruction, especially if it was a positive or negative experience, might influence how you approach it in the future? Why or why not?
- Is there something else I haven't included here that might affect your participation in or feelings about the type of instruction?
- Is there anything else you would like to add to my thinking about this relationship?

Of the students in the analytic sample, 37% were female, an overrepresentation from the total population of students (28% female). Most were White (50%), followed by Asian-Pacific Islander (27.9%), Multiracial (13.5%), African-American (5%), and Latino/a (3.6%) students. This followed closely in line with the racial demographics of the total population, with White, Asian-Pacific Islander, and Latino/a students being slightly underrepresented, while African-American and Multiracial students were overrepresented by nearly double. There were also two American Indian/Alaska Native students in the total population that were not represented in the sample.

Additionally, the predominant class year was second-year (53.1%), followed by first-year (27.4%), third-year (18.3%), and fourth-year (1.2%). These class year percentages are expected, given that the courses studied here are introductory; however, first-year students were underrepresented, while second- and third-year students were overrepresented. A large majority of students were U.S. Citizens (88%), somewhat over-representative of the total population of 84%, while international students were somewhat underrepresented (9% in the sample and 13% of the total population).

A majority of the students reported a current GPA of 3.5 or higher (56%), consistent with the total population. Furthermore, most students expected an “A” grade in their current course (55%) and attended the lecture portion of the course “always” (64%). The distribution of students across the five courses was mostly uniform, with a slight underrepresentation of EECS 215 and MECHENG 211 and a slight overrepresentation of EECS 280 and BIOMEDE 231.

Table 8
Social-Demographic and Course-Related Characteristics of the Analytic Sample

	Sample (n=242)		Total Population (n=539)[a]	
	n	%	n	%
Year in College				
First	66	27.4	188	34.8
Second	128	53.1	263	48.8
Third	44	18.3	70	13.0
Fourth	3	1.2	18	3.4
Gender				
Female	96	37.0	151	28.0
Male	146	63.0	388	72.0
Race/Ethnicity				
White	111	50.0	281	52.1
African-American	11	5.0	15	2.7
American Indian/Alaska Native	0	0.0	2	0.3
Asian-Pacific Islander	62	27.9	170	31.5
Latino/a	8	3.6	29	5.4
Multiracial	30	13.5	42	7.9
Citizenship Status				
U.S. Citizen	212	87.6	451	83.7
Permanent Resident (green card)	8	3.3	19	3.5
International Student (F-1, J-1, M-1, or other visa)	22	9.1	69	12.8
What is your current GPA?				
3.5 or higher	135	55.8	280	51.9
3.0 to 3.49	78	32.2	199	36.9
2.5 to 2.99	22	9.1	50	9.3
2.0 to 2.49	6	2.5	8	1.6
0 to 1.99	1	0.4	2	0.3
What is your current/intended major?				
Aerospace Engineering	7	2.9	13	2.4
Biomedical Engineering	62	25.6	91	16.9
Chemical Engineering	43	17.8	101	18.7
Civil Engineering	0	0.0	8	1.5
Climate and Meteorology	1	0.4	2	0.4
Computer Engineering	19	7.9	45	8.3
Computer Science	8	3.3	19	3.5
Data Science	41	16.9	72	13.4
Electrical Engineering	12	5.0	21	3.9
Engineering Physics	1	0.4	15	2.8
Industrial and Operations Engineering	1	0.4	4	0.7
Materials Science and Engineering	4	1.7	10	1.9
Mechanical Engineering	30	12.4	41	7.6
Naval Architecture and Marine Engineering	2	0.8	10	1.9
Nuclear Engineering and Radiological Sciences	1	0.4	9	1.7
Non-Declared Engineering[b]	N/A	N/A	53	9.8
Space Science and Engineering	0	0.0	0	0.0
Non-Engineering	10	4.1	25	4.6
Course				
BIOMEDE 231	63	26.0	96	17.8
CHE 330	41	16.9	143	26.5
EECS 215	29	12.0	73	13.5
EECS 280	76	31.4	148	27.5
MECHENG 211	33	14.7	79	14.7

[a]Information for the total population was provided from the university registrar and adapted to the questions provided to students in the surveys (if applicable); [b]Students were not offered an "undeclared/non-declared" option in Survey 1; this information was only provided from the university registrar;

Table 8 (Cont.)
Social-Demographic and Course-Related Characteristics of the Analytic Sample

	Sample (n=242)	
	n	%
What is your expected grade in the course?[c]		
A+/A-	133	55.0
B+/B-	92	38.0
C+/C-	14	5.8
D or below	3	1.2
About how frequently did you attend lecture this semester?[c]		
Always (100% of the time)	155	64.0
Most of the time (75% of the time)	73	30.2
About half the time (50% of the time)	10	4.2
Sometimes (25% of the time)	4	1.6
Never	0	0.0

[c]Information for this question was not available from the university registrar.

Methods of Data Analysis

I used both quantitative and qualitative analysis methods to study the data I collected in this project. Specifically, I studied student survey data using descriptive statistics, ANOVAs/ MANOVAs, dependent t-tests for paired samples, Pearson product-moment correlations, and hierarchical multiple regression models. I examined the student focus group data by analyzing transcripts through directed content analysis.

Descriptive Statistics

First, I conducted an initial analysis of the data by compiling descriptive statistics from the collected surveys. Using this descriptive information, I identified what types of instruction were used most often in these courses and how students generally responded to them, which helps to address Research Question 1 (“What types of instruction are being used in introductory engineering courses at a large research university?”). For example, using this descriptive information, I can answer basic questions regarding what types of instruction are used in the engineering classroom and how often they are utilized throughout the semester using mean scores for each type of instruction collected in Survey 1. Furthermore, I compiled descriptive information on how students generally responded to each of these activities to examine whether students showed resistance to the use of EBIP, as anticipated by instructors, or responded in more positive ways. This descriptive information helps to address Research Question 2 ("How do students respond to different kinds of instruction in these courses? How does their previous experience with different kinds of instruction influence their response to its use in their current course?").

MANOVA/ANOVA/Dependent T-Test for Paired Samples

In addition to basic descriptive information about the types of instruction used in these courses and students' response to their use, it is important to understand to what extent these types of instruction or students' responses differ by various groups. The Analysis of Variance (ANOVA) test is a statistical approach used to analyze the differences among two or more group means. For the ANOVA test, the null hypothesis is that there is no variation or difference among the groups (i.e., the group means are statistically the same). I specifically used a one-way ANOVA to examine the differences between groups. Since the types of instruction generally fit into categories of the ICAP framework (groups) and the student response constructs can be aggregated by their means or total scores (sum of all responses) as a continuous variable, I first examined the differences in the use of both individual types of instruction and each classification in the ICAP framework across the five courses in this study. In other words, to better understand the variation in the types of instruction students often see in various courses across different disciplines, these tests addressed the extent to which different types of instruction were used in these five engineering classrooms.

Second, I examined the differences in student response by ICAP classification to better understand in what ways students responded to these types of instruction in their classrooms. Because of possible correlation between student response constructs in my surveys, I also included a Multivariate Analysis of Variance (MANOVA) test in my examination of these response items to eliminate possible Type I errors that might result from using the ANOVA test only. These analyses address Research Questions 1 and 2 by observing whether or not types of instruction differed significantly by course, and how students generally responded to the use of EBIP (i.e., interactive, constructive, and active practices). In other words, this approach allowed me to analyze whether all students respond to these types of instruction in the same ways. I also used a dependent t-test for paired samples to examine whether or not the response scores between students' prior and current response to the same type of instruction differed significantly.

Pearson Product-Moment Correlation

The Pearson product-moment correlation (or Pearson correlation coefficient) is a statistical test that measures the strength and directionality (i.e., positive or negative) of the association between two variables. The values of the Pearson correlation coefficient can range from -1 (perfect negative relationship) to 0 (no relationship) to +1 (perfect positive relationship). Examining the strength in the relationships between response constructs (i.e., value, positivity, and participation) allowed me to determine whether or not these responses had significant relationships with one another. Furthermore, I was able to examine the significance of these relationships within each type of instruction (e.g., relationship between positivity towards interactive types of instruction and participation in interactive types of instruction), across different types of instruction (e.g., relationship between positivity towards interactive types of instruction and seeing value in passive types of instruction), and across prior and current responses to these types of instruction (e.g., relationship between positivity in prior course and positivity in current course).

Hierarchical Multiple Regression

Finally, I expand upon these analyses by building a hierarchical multiple regression model to examine the relationship between students' prior and current responses to various types of instruction used in the engineering classroom, including the frequency with which these types of instruction were being implemented, and how students responded to evaluations of the course and instructor. These controls are inserted into the model in a stepwise approach with the following blocks of variables: student demographics (year in college, gender, race/ethnicity, and citizenship), grade data (students' current GPA and expected grades in the course), and the independent variables of interest, student response to all four types of instruction in the prior and current courses and the frequency of use for each of these four types of instruction. The equation that follows illustrates the final model, where *Evaluation* is the dependent variable, α is the constant term (i.e., the result if all predictors were equal to zero), and β_n represents the coefficient term for each block of variables in the model:

$$\text{Evaluation} = \alpha + \beta_1\text{StudentDemographics} + \beta_2\text{GradeData} + \beta_3\text{PriorResponse} + \beta_4\text{UseofInstruction} + \beta_5\text{CurrentResponse} + \varepsilon$$

All standard errors were clustered by the current course in which students were enrolled (i.e., the sampled courses in this study).

Directed Content Analysis

In addition to the survey data collected in this study, I used focus group data to provide a deeper understanding of why students responded in various ways for each type of instruction. I transcribed all focus group interviews as a way to become more familiar with the themes that emerged from these conversations. Given that this research builds on existing theory about the relationships between types of instruction and student response, I chose to take a directed approach to analyzing transcripts from these focus groups through directed content analysis (Hsieh & Shannon, 2005; Potter & Levine-Donnerstein, 1999). The goal of directed content analysis is to further extend or confirm a theoretical framework or hypothesis about a phenomenon. This approach is much more structured than the conventional content analysis technique, which is inductive in nature. Inductive content analysis begins with the raw qualitative data, and through an open coding process, researchers generate themes and codes to develop a model or theory about the experiences or processes that are discussed in the data (Hickey & Kipping, 1996). To conduct the directed content analysis, I used the conceptual framework from Chapter 2 to identify key concepts and relationships that guided the interview protocol for these focus groups (Table 7).

Limitations

Although this research study does improve upon prior research examining student response to the types of instructional practices encountered in the engineering classroom, it is not without limitations. The first limitation is that this study relies solely on self-reported measures. A common issue with research studies examining non-cognitive skills, particularly in educational settings, is the potential for bias in self-reported measures (West, 2014). Self-reported measures can be limited by social desirability bias (i.e., choosing a response because of social pressures), reference bias (i.e., differing standards of comparisons among respondents), and trouble with retrieval/recall (Sudman, Bradburn, & Schwarz, 1996). Though direct measures of student participation and repeated inquiry about value and positivity towards types of instruction would be preferable, the use of self-reported measures makes a study of this scope manageable.

Nonetheless, there is merit to understanding how students perceive their experiences in the classroom – whether correctly or otherwise – and how they subsequently respond, which is one of the research questions that this study addresses.

A second limitation is the scope of this research study. This study only invited participants from five courses across five disciplines at a competitive College of Engineering at one highly selective institution. Thus, the findings are most applicable to similar courses (large gateway courses) at similar types of institutions. Furthermore, although the courses were randomly selected from the five engineering disciplines, students were not randomly selected in each of these courses. As indicated in Table 8, while some percentages of students from various groups were similar to the total population in these courses, other groups of students were overrepresented in the sample (e.g., female students), and thus the results presented in the following chapters are generalizable to populations distributions similar to those in this sample.

Chapter 4: Quantitative Results

In Chapter 4, I present the results of my quantitative analysis. Given the three research questions in Chapter 1, I established a more specific set of questions that will be addressed by the quantitative results from this study:

1. What types of instruction are being used in introductory engineering courses at a large research university?
    a. Do these types of instruction vary by class/instructor?
2. How do students respond to different kinds of instruction in these courses? How does their previous experience with different kinds of instruction influence their response to its use in their current course?
    a. Do these responses vary by the class in which they are currently enrolled?
3. What relationships exist between prior response, current response, the frequency with which each type of instruction is used in the current course, and how students subsequently evaluate the course and instructor?
    a. How does student response to each type of instruction change between prior and current courses?
    b. Does student response to one type of instruction correlate with the student response to any of the three other types of instruction? Furthermore, does prior student response correlate with current student response?

c. How might prior and current student response to each type of instruction and the frequency with which the type of instruction is used in the current course impact students' overall evaluation of the course and instructor?

This chapter is divided into three separate sections, which address these questions. In the first section, I seek to address the overall nature of the types of instruction that student perceive to be used most often in the engineering classroom (Research Question 1). In the second section, I investigate student response to four most commonly-used types of instruction (one for each of the ICAP classifications) in prior courses and their current course (Research Question 2). In the third section, I explore the relationships between each of these elements (students' prior response to four types of instruction, their perceived use of these types of instruction in the current classroom, and their subsequent response to the four types of instruction in their current courses; Research Question 3).

Figure 7 provides an updated illustration of how these four research questions map onto the conceptual framework in Figure 4 of Chapter 2. For example, Research Questions 1 and 2 explore the three individual elements of the conceptual framework (use of types of instruction, response to four of the most common practices prior to this course, and subsequent response to these same practices), while Research Question 3 examines the relationship between each of these elements, and the frequency with which the instruction was perceived to be used in the current course.

Types of Instruction Encountered in the Engineering Classroom

In this section, I address Research Question 1 by exploring the types of instruction that students perceive are most commonly-used in these engineering courses. As described in Chapter 3, I operationalized the types of instruction used in the engineering classroom using Chi and

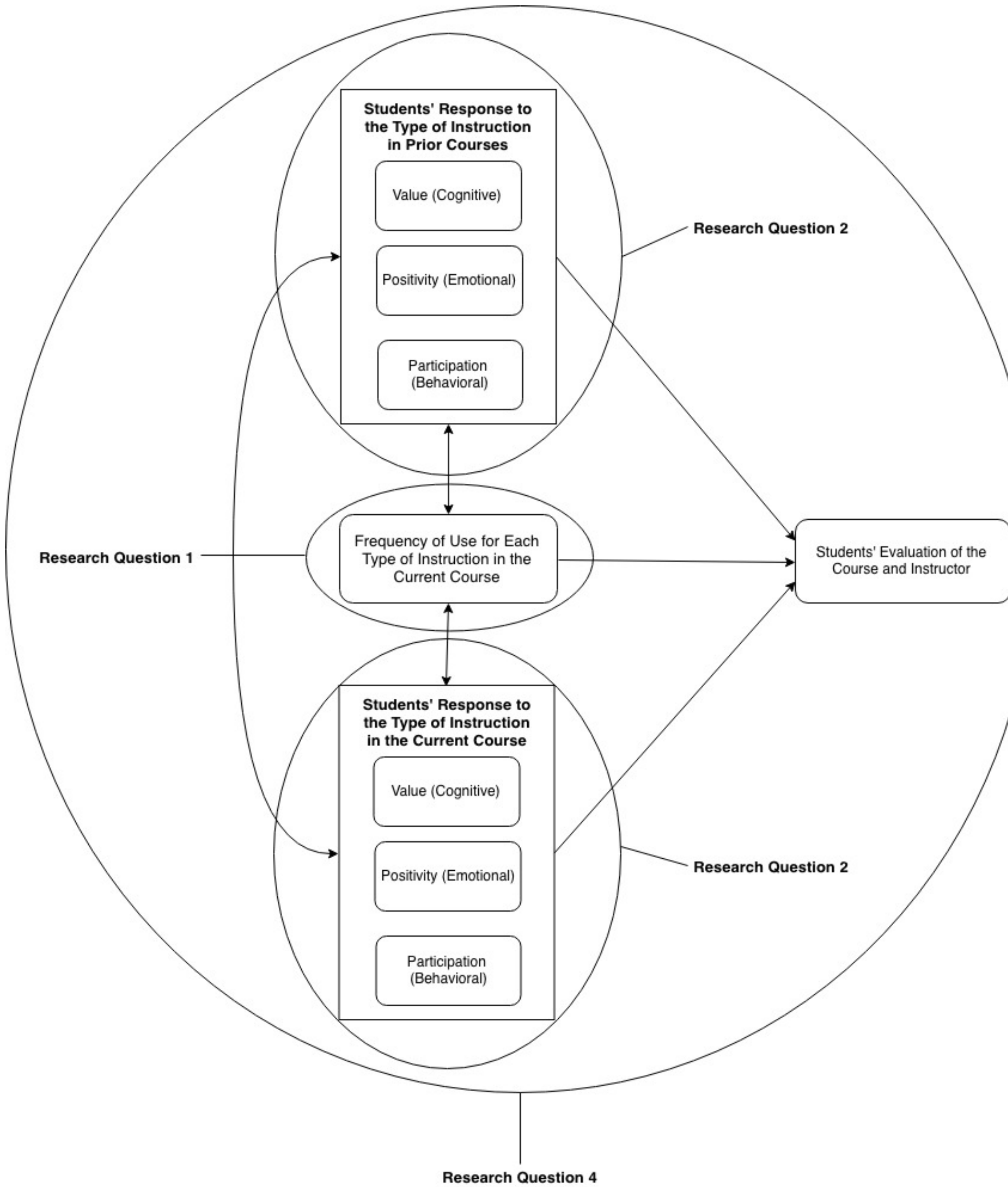

Figure 7. Expanded framework for the relationships between type of instruction (including students' prior experiences with the type of instruction) and student response using quantitative research questions.

Wylie's (2014) ICAP framework. From this framework, I asked students to describe the frequency with which they experienced the 21 most commonly-used types of instruction and established a four-factor structure for them which loosely fit the ICAP nomenclature. All four factors had construct reliabilities above 0.70 (Table 9). As noted in Chapter 2, these types of instruction are presented here and throughout this chapter in reverse from the order in which they appear in the acronym (PACI rather than ICAP).

Table 9
Descriptives and ANOVA of Differences Among Courses for Each Type of Instruction

Type of Instruction	M	SD	α	F	η^2
Passive	**3.94**	**0.71**	**0.73**	**7.88***	**0.13**
*Listen to the instructor lecture during class (**Listen**).*	*4.28*	*0.80*		*4.76*	*0.08*
Watch the instructor demonstrate how to solve problems.	2.88	0.92		16.32*	0.23
Get most of the information needed to solve the homework directly from the instructor.	2.08	1.19		24.16*	0.31
Active	**2.28**	**0.62**	**0.74**	**8.08***	**0.13**
Make individual presentations to the class.	2.70	0.53		19.52*	0.26
Be graded on my class participation.	2.55	0.91		12.63*	0.19
Solve problems individually during class.	2.98	1.20		19.15*	0.26
*Answer questions posed by the instructor during class (**Answer Q's**).*	*2.90*	*1.21*		*5.44**	*0.09*
Ask the instructor questions during class.	2.48	1.28		0.75	0.01
Preview concepts before class by reading, watching videos, etc.	3.76	1.41		0.53	0.01
Constructive	**3.45**	**0.67**	**0.81**	**3.65**	**0.06**
Make and justify assumptions when not enough information is provided.	3.37	1.12		6.97*	0.11
Find additional information not provided by the instructor to complete assignments.	4.08	1.21		1.70	0.03
Take initiative for identifying what I need to know.	3.28	0.99		2.04	0.04
*Brainstorm different possible solutions to a given problem (**Brainstorm**).*	*3.23*	*1.16*		*4.39*	*0.07*
Assume responsibility for learning material on my own.	3.07	1.00		14.86*	0.21
Solve problems that have more than one correct answer.	1.91	1.34		19.23*	0.26
Interactive	**2.59**	**0.84**	**0.71**	**14.48***	**0.21**
Solve problems in a group during class.	4.48	1.31		4.99*	0.08
Do hands-on group activities during class.	3.41	1.23		3.97	0.07
*Discuss concepts with classmates during class (**Discuss**).*	*3.34*	*1.19*		*10.78**	*0.16*
Work in assigned groups to complete homework or other projects.	2.33	1.42		14.13*	0.21
Be graded based on the performance of my group.	1.14	1.27		0.70	0.01
Study course content with classmates outside of class.	1.51	1.42		9.80*	0.15

Note: Italicized types of instruction indicate those used in the section discussing student response.
Response scale: 1 = Almost never (<10% of the time); 2 = Seldom (~30% of the time); 3 = Sometimes (~50% of the time); 4 = Often (~70% of the time); 5 = Very often (>90% of the time)
$^*p<0.001$

Differences Across Individual Types of Instruction

The use of each type of instruction varied within each of the ICAP constructs. The means and standard deviations for students' perceived use of each type of instruction is presented in Table 9. For example, passive types of instruction were mixed, with "listen to the instructor lecture during class" used *often* (mean = 4.28), "watch the instructor demonstrate how to solve problems" used *sometimes* (mean = 2.88), and "get most of the information needed to solve the homework directly from the instructor" used *seldom* (mean = 2.08). Active types of instruction were more consistent, averaging between 2.48 (*seldom*/*sometimes*; "ask the instructor questions during class") and 3.76 (*often*; "preview concepts before class by reading, watching videos, etc."). Constructive types of instruction featured varied results much like passive types of instruction with "solve problems that have more than one correct answer" used *seldom* (mean = 1.91) and "find additional information not provided by the instructor to complete assignments" used *often* (mean = 4.08). Finally, for interactive types of instruction, "solve problems in a group during class" was used *often* to *very often* (mean = 4.48) across all courses, while "be graded based on the performance of the group" was used *almost never* (mean = 1.14).

Looking specifically at the four types of instruction that were most commonly-used in our pilot study (DeMonbrun et al., 2017), which were also used for the student response portions of Surveys 1 and 2, it appears that only "Listen" was the most commonly-used in its ICAP category; however, according to the mean scores across all courses, the italicized types of instruction were used anywhere from *seldom* to *often*, depending on the course, indicating that these four types of instruction were at least used to some extent in each of the classrooms in this study.

In order to better understand whether these types of instruction were used similarly across all five courses (Research Question 1a), I performed a series of analysis of variance (ANOVA) tests to determine if there was a significant difference in the means across the groups (courses). These results are also provided in Table 9. As indicated in the table, 13 of the 21 types of instruction were used with significantly different frequency across each of the courses ($p<0.001$).

The η^2 (effect size for each ANOVA) is also included in Table 9 as reference for the size of the differences in the use of each type of instruction between these courses (Miles & Shevlin, 2001). In other words, while the ANOVA test answers whether or not the groups are statistically different, the effect size answers how large the differences are. So, when comparing two different effect sizes (e.g., 0.10 and 0.20), the larger number represents a larger difference between groups. Based on the interpretations of ANOVA effect sizes[2] prescribed by Cohen (1988), 10 of the 16 types of instruction with significant differences across courses had a large effect size (≥0.14). These large effects were mixed across ICAP designations: two were passive types of instruction, three active, two constructive, and three interactive. The remaining six significant differences had a medium effect size (≥0.06), with one of these being a passive type of instruction, one active, two constructive, and two interactive. Thus, while each of these courses included a mix of traditional passive lecture and active learning, students' observations of the frequency of each of these types of instruction differed across courses.

Difference Across ICAP Constructs

While the previous analyses tell us about the use of certain types of instruction in each course, I also examined how these constructs of interactive, constructive, active, and passive types of instruction were broadly used in the course to better understand the type of interaction that was expected of each student. Specifically, I took the mean scores of each of these types of instruction grouped by ICAP classification and examined the overall use across all five courses in the study (bolded items in Table 9). Passive types were used *often* (mean = 3.94), active types were used *seldom* (mean = 2.28), constructive types were used between *sometimes* and *often* (mean = 3.45), and interactive types were used between *seldom* and *sometimes* (mean = 2.58). I

[2] Cohen's (1988) guidelines for effect sizes of ANOVAs are different than those used for t-test of means/proportions, which generally report 0.2 (small), 0.5 (medium), 0.8 (large).

also performed a series of analysis of variance (ANOVA) tests to determine if there was a significant difference in the means across the groups (courses). These differences across courses were significant for three of the four ICAP constructs ($p<0.001$). Only constructive types of instruction were used in similar frequencies across each of the courses. For the other three types of instruction, the effect size of these differences varied. For example, the effect size for interactive types of instruction was large ($\eta^2 = 0.21$), while the effect sizes for differences in the use of passive and active types of instruction across courses was moderate ($\eta2 = 0.13$ for both types of instruction). This is demonstrated in the range of mean scores between these courses, with interactive types of instruction having a much larger range than active types of instruction.

Summary for Types of Instruction Encountered in the Engineering Classroom

With regards to Research Question 1 (What types of instruction are being used in introductory engineering courses at a large research university?), students indicated that there were many different types of instruction used in each of their courses. This suggest that, at large research universities like the University of Michigan, concerns about the lack of use of EBIP in the engineering classroom (Friedrich et al., 2007; Handelsman et al., 2004; Hora et al., 2012; PCAST, 2012; Singer et al., 2012) may not be as strong. Although some passive types of instruction were used *often* (e.g., "listen to instructor lecture during class"), it is clear that instructors in these courses were also sometimes or, in a few cases, often using active types of learning in their classrooms. The five courses in this study were randomly selected, and yet students indicated that a variety of active, constructive, and interactive types of instruction were used at least *sometimes* and many were used *often* in each of these courses. In fact, only one of the 21 types of instruction ("be graded based on the performance of my group") had low enough mean scores to suggest that this was rarely, if ever, used in these engineering classrooms (mean=1.14).

These results are context-specific as indicated in the differences in the frequency of use across each of the courses in this sample (Table 9). It is clear from some of the larger differences in mean scores across courses, that faculty for these courses might have different types of instruction that they prefer to use in their courses. This is even true for some passive types of instruction, as “get most of the information needed to solve the homework directly” had the largest effect size of the 21 types of instruction ($\eta^2 = 0.31$), and thus had the largest variance in its perceived use across courses. Across the ICAP classifications, interactive types of instruction had the largest variation between courses, but even this large effect size ($\eta^2 = 0.21$) amounted to a difference in about one point in mean scores across courses, reflecting the difference between *seldom* and *sometimes* using these types of instruction.

Although these findings are promising, there should be some caution mixed in with these results. In Survey 1, I asked students about *whether or not they did* each type of instruction in the course. This is not the same as asking students how often the instructor *used* or *asked students to do* each type of instruction. In other words, students may have chosen to study with peers inside or outside of class without being prompted by the instructor to do so. Additionally, constructive types of instruction like “take initiative for identifying what I need to know” may be conceptualized differently by students than what instructors would expect from this type of instruction. Perhaps, a student believes that listening to the instructor lecture constitutes “taking initiative,” while this is not the conceptualization that Chi and Wylie (2014) give for constructive types of instruction. Put together, these results show potential for the increased use of more active types of instruction, but additional research (preferably with classroom observations) should verify the connection between students’ perceptions and what occurs in the classroom.

Student Response to Types of Instruction

Research Question 2 addresses how students responded to types of instruction used in their prior engineering courses, including how much they valued these types of instruction, how positively they felt about them, and whether or not they participated in or demonstrated more negative responses to these practices. As described in Chapter 3, I operationalized the student response framework using Fredricks et al.'s (2004) concept of classroom engagement. All response factors had construct reliabilities above 0.70 (fifth column of Table 10 with α symbol). From this framework, I took the 13 items used to assess the three types of student engagement (cognitive, emotional, and behavioral; see Table 4 for a list of these items) and established a three-factor structure measuring student response to types of instruction (value, positivity, and participation). I then asked students in Survey 1 of this study to indicate their typical response in a prior course to the four most commonly-used types of instruction as identified in our prior research (Lecture, Answer Q's, Brainstorm, Discuss; DeMonbrun et al., 2017).

Table 10
MANOVA and ANOVA of Differences in Prior Student Response to Types of Instruction by Course

	MANOVA		ANOVA			
Student Response to Type of Instruction	Wilks λ	F	F	α	ICC	DEFF
Listen	0.89	0.85				
Value			1.77	0.94	0.01	0.98
Positivity			1.99	0.80	0.06	0.97
Participation			0.44	0.83	0.00	1.01
Answer Q's	0.94	0.64				
Value			0.13	0.93	0.00	1.03
Positivity			0.81	0.73	0.01	1.01
Participation			0.99	0.85	0.01	1.01
Brainstorm	0.95	0.62				
Value			0.36	0.87	0.00	1.02
Positivity			0.78	0.76	0.00	1.00
Participation			0.41	0.87	0.00	1.01
Discuss	0.90	0.75				
Value			0.74	0.89	0.00	1.00
Positivity			1.97	0.75	0.04	0.97
Participation			0.20	0.85	0.00	1.02

Response scale: 1 = Almost never (<10% of the time); 2 = Seldom (~30% of the time); 3 = Sometimes (~50% of the time); 4 = Often (~70% of the time); 5 = Very often (>90% of the time)

Research Question 2 also addresses how students responded to these same types of instruction in their current engineering courses. In addition to the 13 items used to assess the three types of student engagement (cognitive, emotional, and behavioral), I added three items to assess students' evaluation of the course/instructor (Table 4), thus establishing a four-factor structure measuring student response to types of instruction (value, positivity, participation, and evaluation). Similar to the questions on prior student response, I then asked students in Survey 2 of this study to describe their typical response to the same four types of instruction as used in Survey 1. All four factors had construct reliabilities above 0.70, as indicated in Table 11. In both Surveys 1 and 2, for reverse-coded items that would negatively impact participation (e.g., "I did not actually participate in the activities"), a higher score indicates that the student reported *almost never* or *seldom* having that response, while lower scores represent *often* or *very often* doing so.

Table 11
MANOVA and ANOVA of Differences in Current Student Response to Types of Instruction by Course

	MANOVA		ANOVA			
Student Response to Type of Instruction	Wilks λ	F	F	α	ICC	DEFF
Listen	0.94	0.64				
Value			1.93	0.83	0.02	0.96
Positivity			1.84	0.87	0.02	0.97
Participation			0.94	0.87	0.03	1.02
Answer Q's	0.91	0.74				
Value			0.87	0.74	0.04	1.05
Positivity			1.05	0.76	0.03	0.96
Participation			1.52	0.74	0.03	1.04
Brainstorm	0.92	0.73				
Value			1.20	0.71	0.05	0.95
Positivity			1.58	0.75	0.01	1.00
Participation			1.01	0.77	0.01	0.98
Discuss	0.88	1.53				
Value			1.16	0.88	0.04	0.95
Positivity			1.45	0.78	0.03	0.97
Participation			1.39	0.82	0.01	1.02
Evaluation	0.93	0.69	1.38	0.88	0.04	0.98

Response scale: 1 = Almost never (<10% of the time); 2 = Seldom (~30% of the time); 3 = Sometimes (~50% of the time); 4 = Often (~70% of the time); 5 = Very often (>90% of the time)

Testing for Clustering Bias

A primary concern in studying students in a classroom setting is the clustering bias of the responses for each course. In other words, analyses of data in hierarchical structures as single-level data can lead to misleading results (e.g., increasing the likelihood of Type I errors). To examine the variation in student response across courses before analyzing the differences in student response across types of instruction, I calculated the average response by course to determine whether or not prior and current responses differed across the courses in my sample. I first conducted a MANOVA test to see it there was a significant difference for any of the three prior response constructs and four current response constructs (Tables 10 and 11, respectively) across these courses (groups). In this case, the MANOVA test is used to eliminate any potential biases from correlation between the response constructs. The MANOVA tests for all four types of instruction (passive, active, constructive, and interactive) were all non-significant based on Wilks λ and F tests ($p>0.05$). I also conducted an ANOVA on each individual response construct to test if there was a significant difference in the individual response constructs across these courses. All ANOVA tests were also non-significant ($p>0.05$). These findings provide support for treating the student as the primary unit of analysis (i.e., no multilevel modeling).

To further confirm whether or not multilevel modeling was needed for my data, I calculated the interclass correlation (ICC) and design effect (DEFF) statistics for each response. Generally, any non-zero statistic for the ICC indicates that there is some course-level variation in the sample; however, a non-zero statistic does not mean that a multilevel model is necessary for the analysis. Peugh (2010) recommends using the DEFF statistic in combination with the ICC to determine the need for multilevel modeling. Specifically, any DEFF statistic greater than 2 indicates the need for a multilevel model (Muthén, 1991, 1994; Muthén & Satorra, 1989, 1995). Although I did find non-zero ICCs across each student response, the DEFF statistic for every response was less than 2. Thus, I report all statistical tests involving student response in the aggregate (i.e., all courses together rather than broken down by class) throughout the rest of this chapter.

Student Response to Types of Instruction in Prior Courses

Students' prior responses to each of these types of instruction were mixed (Table 12). For "Listen" (passive instruction), students reported *often* finding value this type of instruction (mean = 3.78), while only *sometimes* feeling positive about the activity and instructor (mean = 2.83) and *sometimes* participating in the activity (mean = 3.20). With "Answer Q's" (active instruction) and "Brainstorm" (constructive instruction), students responded similarly by reporting *often* finding value in the activity (mean = 3.73 and 3.82, respectively), but only *sometimes* feeling positive about the activity (mean = 2.66 and 2.78, respectively) and *sometimes* participating in the activity (mean = 3.08 and 3.10, respectively). When students were asked to "Discuss" (interactive instruction), their responses for value in the activity shifted to much lower ratings. Students indicated *seldom* finding value in this activity (mean = 2.01), but still indicated that they *sometimes* felt positively about the activity/instructor (mean = 2.73) and *sometimes* participated in the activity (mean = 3.23).

To statistically examine these differences between student response and the types of instruction in this study, I performed a series of ANOVA tests to determine if there were significant differences in the three response constructs across these four types of instruction. These results are also indicated Table 12. The only student response outcome with a significant amount of variation between types of instruction was the value response ($F=52.57$; $p<0.001$). Interestingly, the only type of instruction that appears to be significantly different in the value response is "Discuss" (mean = 2.01). Students' perceptions on the value placed on this type of instruction were nearly two points lower than the other three types of instruction with means between 3.73 and 3.82. There were no differences between the types of instruction and the positivity and participation constructs.

Student Response to Types of Instruction in Current Courses

Similar to the findings in the section on student response to types of instruction in prior courses, the responses to each of these types of instruction in the current course were also mixed (Table 13). For "Listen" (passive instruction), students reported only *sometimes* finding value in (mean = 3.25), *sometimes* feeling positive about (mean = 3.02), and *sometimes* participating in the activity (mean = 3.05). Similar findings were noted for "Answer Q's" (active instruction; value mean = 3.16, positivity mean = 3.20, and participation mean = 3.23) and "Brainstorm" (constructive instruction; value mean = 3.13, positivity mean = 3.02, and participation mean = 3.24). When students were asked to "Discuss" (interactive instruction) in their current course, they reported much lower ratings in the value of this activity, similar to the inclinations from their prior response. Students indicated *seldom* finding value in this activity (mean = 2.01), but reported that they *sometimes* felt positively about the activity/instructor (mean = 2.73) and *sometimes* participated in the activity (mean = 3.23).

Table 12
Means and ANOVA of Differences in Prior Student Response by Type of Instruction

	Type of Instruction				
Student Response	Listen	Answer Q's	Brainstorm	Discuss	F
Value	3.78	3.73	3.82	2.01	52.57*
Positivity	2.83	2.66	2.78	2.73	1.37
Participation	3.20	3.08	3.10	3.23	1.10

Response scale: 1 = Almost never (<10% of the time); 2 = Seldom (~30% of the time); 3 = Sometimes (~50% of the time); 4 = Often (~70% of the time); 5 = Very often (>90% of the time); * $p<0.001$

Table 13
Means and ANOVA of Differences in Current Student Response by Type of Instruction

	Type of Instruction				
Student Response	Listen	Answer Q's	Brainstorm	Discuss	F
Value	3.25	3.16	3.13	2.17	19.40*
Positivity	3.02	3.20	3.02	3.17	0.90
Participation	3.05	3.23	3.24	3.20	0.82

Response scale: 1 = Almost never (<10% of the time); 2 = Seldom (~30% of the time); 3 = Sometimes (~50% of the time); 4 = Often (~70% of the time); 5 = Very often (>90% of the time); * $p<0.001$

To statistically examine these differences between current student response and types of instruction, I also performed a series of ANOVA tests to determine if there was a significant difference in the three response constructs across these four types of instruction. These results are also indicated in

. Similar to the findings about student response to prior types of instruction, the only student response outcome with a significant amount of variation between types of instruction was the value response ($F=19.40$; $p<0.001$), and the major difference in these types of instruction were between "Discuss" (mean = 2.17) and the other three types of instruction (means between 3.13 and 3.25). In fact, the value mean for "Listen" was the highest of all four types of instruction (mean = 3.25). There were no significant differences between the types of instruction and the positivity and participation constructs.

Summary for Student Response to Types of Instruction

With regards to Question 2, students' prior responses were consistent for three of the four types of instruction in this study. For the passive, active, and constructive types of instruction, students indicated *often* finding value in these activities, while *sometimes* feeling positive about and participating in them. Although the findings for the interactive type of instruction were consistent for positivity and participation, students reported much lower scores for the value of this type of activity. This finding was also reflected with regards to their response to their current courses as, for passive, active, and constructive instruction, students *sometimes* felt positive about and participated in these activities. On the other hand, their value in these activities did drop from *often* to *sometimes* between the prior and current responses. The findings for the interactive instruction in the current course were also similar to prior responses. Students shared *sometimes* responding positively about and participating in this activity, while only *seldom* finding value in it.

These results for both prior and current response indicate that students perhaps struggle with finding the tangible benefits of more interactive types of instruction and might not feel that their "return on investment" is worth the effort undertaken in these activities; however, students are willing to still think positively about and participate in interactive instruction, regardless of their proclivities about its usefulness. Although one might expect students to still participate in an activity regardless of their feelings about it – especially if the activity weighed heavily on their final grade – the positivity about this type of instruction is perplexing. Perhaps, students still enjoy these activities and/or know that they instructor has their best interests in mind, but they have yet to fully benefit from the activity versus, say, doing an activity by themselves.

Changes Between Prior and Current Student Response

In this final section, I address Research Question 3 by exploring the relationships between students' prior experiences with the four types of instruction in this study, their perceived use of these types of instruction in the current course, and their subsequent response to the same types of instruction in the current course. First, in order to determine changes between the value, positivity, and participation responses for these types of instruction between prior and current courses, I compared the response scores using a dependent t-test for paired samples. The purpose of this analysis was simply to examine whether or not there were significant changes between how students responded to these four types of instruction in their prior courses (as surveyed at the beginning of their current course), and how they responded in their current course (as surveyed at the end of their current course). The results are provided in Table 14.

When students were asked to "Listen," they reported finding value in this type of instruction closer to *often* (mean = 3.78) in prior courses, but only *sometimes* in the current course (mean = 3.25). This represented a significant difference in their scores from prior to current response ($p<0.001$). For “Answer Q’s,” students reported similar differences in value between prior and current response, from 3.73 to 3.16 ($p<0.001$), and similar increases in positivity, from 2.66 to 3.20 ($p<0.001$). Responses differed, however, in that students reported greater participation levels from 3.08 to 3.23 ($p<0.001$). Similar decreases and increases were reported for “Brainstorm,” as students expressed a decrease in value (3.82 to 3.13; $p<0.001$) and an increase in positivity (2.78 to 3.02; $p<0.001$) and participation (3.10 to 3.24; $p<0.001$). Finally, for “Discuss,” students reported an increase in positivity (2.73 to 3.17; $p<0.001$). These results suggest that there may be significant differences between students’ prior and current responses to the same types of instruction; however, it may also be that students are simply responding to the most current experience in their current course, irrespective of their feelings in the prior course. These relationships are further uncovered in the next section.

Table 14
Mean Scores for Student Response to Types of Instruction in Prior and Current Courses (n=242)

Type of Instruction	Listen		Answer Q’s		Brainstorm		Discuss	
Student Response	Prior	Current	Prior	Current	Prior	Current	Prior	Current
Value	3.78	3.25	3.73	3.16*	3.82	3.13*	2.01	2.17
Positivity	2.83	3.02	2.66	3.20*	2.78	3.02*	2.73	3.17*
Participation	3.20	3.05	3.08	3.23*	3.10	3.24*	3.23	3.20

Response scale: 1 = Almost never (<10% of the time); 2 = Seldom (~30% of the time); 3 = Sometimes (~50% of the time); 4 = Often (~70% of the time); 5 = Very often (>90% of the time); Note: Significance values are for paired sample t-test of the difference between prior and current values.; * $p<0.001$

The Relationship Between Prior and Current Student Response

Next, to investigate the statistical relationships between the constructs for student response to each type of instruction in the current course (Research Question 3b), I calculated the correlation coefficients for the relationships between each response construct (Table 15). The grey cells of the table represent the correlations between types of responses to the same type of instruction. For example, the rows and columns numbered 1-3 represent the correlations between types of student response to “Listen.”

Using Evans’s (1996) guidance on interpreting the strength of correlations, I found that most of the relationships within each type of instruction were “moderate” (0.3–0.5) to “strong” (0.5–1.0) For “Listen” (passive), these relationships were between 0.61 and 0.75 (strong). For “Answer Q’s” (active), these relationships were between 0.52 (moderate) and 0.70 (strong). Across “Discuss” (interactive), relationships between student responses were between 0.56 (moderate) and 0.71 (strong). In contrast to these findings, the relationships across “Brainstorm” (constructive) were the only ones that exhibited “weak,” (0.1–0.3) and sometimes negative, relationships. The relationship between participation and positivity was -0.20 (weak and negative) and the relationship between participation and value was -0.29 (weak and negative). This appears to suggest an inverse relationship, whereby a student’s increased value of or positivity regarding “Brainstorm” is related to less participation in the activity, or vice-versa. This relationship is weak, however.

Table 15
Pearson Correlation Coefficient for the Relationship between Current Student Responses for Each Type of Instruction

	1	2	3	4	5	6	7	8	9	10	11	12
Listen												
1. Value	1.00											
2. Positivity	0.61*	1.00										
3. Participation	0.75*	0.70*	1.00									
Answer Q’s												
4. Value	0.26*	0.35*	0.31*	1.00								
5. Positivity	0.29*	0.40*	0.34*	0.68*	1.00							
6. Participation	0.41*	0.43*	0.49*	0.52*	0.70*	1.00						
Brainstorm												
7. Value	0.19	0.23*	0.24*	0.23*	0.21*	0.32*	1.00					
8. Positivity	0.23*	0.26*	0.24*	0.19	0.24*	0.29*	0.71*	1.00				
9. Participation	0.27*	0.22*	0.30*	0.23*	0.29*	0.34*	-0.29*	-0.20*	1.00			
Discuss												
10. Value	0.25*	0.25*	0.26*	0.35*	0.25*	0.22*	0.18	0.16	0.18	1.00		
11. Positivity	0.35*	0.31*	0.33*	0.34*	0.33*	0.32*	0.17	0.16	0.21*	0.65*	1.00	
12. Participation	0.37*	0.31*	0.39*	0.37*	0.34*	0.38*	0.20	0.18	0.30	0.56*	0.71*	1.00

Note: * $p<0.001$

Although I found statistically significant relationships in student responses across *different* types of instruction (the data in Table 15 that is not in shaded cells), most of these were weak in strength. Some notable exceptions included the relationships between student response to the “Listen” (passive) and “Answer Q’s” (active) types of instruction. For example, there was a moderate positive relationship (0.49) between active participation and passive participation. Furthermore, there were moderate positive relationships between active and passive positivity (0.40), active participation and passive positivity (0.43), and active participation and passive value (0.41). This finding suggests that students who find value in, positivity regarding, and participate in “Listen” may find exhibit similar value, positivity, and participation with “Answer Q’s.”

Next, I calculated the Pearson correlation coefficient between both the prior and current response constructs individually within each of the four types of instruction. These results are reported in Table 16. The grey cells of this table represent the relationships between value, positivity, and participation within students’ prior and current courses (i.e., numbers 1-3 represent relationships in the prior course, and numbers 4-6 represent relationships in the current course). Like in the previous table, the asterisks represent the significance of the relationship using the Pearson chi-square statistics at $p<0.001$.

I found mixed results across each of the four types of instruction. For “Listen” (passive), most of the significant relationships were isolated within the prior and current response frameworks (i.e., prior response constructs were mostly significantly associated with other prior response constructs). The two exceptions were that positivity in the prior course was negatively associated with value (-0.21) in the current course, and participation in the prior course was negatively associated with positivity in the current course(-0.24); however, both of these significant relationships were weak. For “Answer Q’s” (active), all three of the response constructs (value, positivity, and participation) in the current course were significantly, negatively associated with the participation in the prior course, suggesting that lower reports of participation in prior courses were associated with higher reports of value, positivity, and participation in the current course, and vice-versa, for this type of instruction. These relationships were weak for positivity (-0.20) and participation (-0.25) and moderate for value (-0.50). There were no significant associations between prior and current response constructs for “Brainstorm” (constructive).

Table 16
Pearson Correlation Coefficient for the Relationship between Student Responses for Each Type of Instruction

	1	2	3	4	5	6
Listen						
1. Prior Value	1.00					
2. Prior Positivity	0.24*	1.00				
3. Prior Participation	-0.40*	0.20*	1.00			
4. Value	-0.08	-0.21*	-0.18	1.00		
5. Positivity	-0.03	0.05	-0.24*	0.61*	1.00	
6. Participation	-0.05	0.07	-0.14	0.75*	0.70*	1.00
	1	2	3	4	5	6
Answer Q’s						
1. Prior Value	1.00					
2. Prior Positivity	0.35*	1.00				
3. Prior Participation	-0.38*	0.17	1.00			
4. Value	0.11	-0.01	-0.50*	1.00		
5. Positivity	0.10	-0.01	-0.20*	0.68*	1.00	
6. Participation	0.09	-0.19	-0.25*	0.52*	0.70*	1.00
	1	2	3	4	5	6
Brainstorm						
1. Prior Value	1.00					
2. Prior Positivity	0.35*	1.00				
3. Prior Participation	-0.46*	0.10	1.00			
4. Value	-0.15	-0.04	-0.02	1.00		
5. Positivity	-0.12	0.07	-0.03	0.71*	1.00	
6. Participation	0.15	-0.02	-0.14	-0.19	-0.02	1.00
	1	2	3	4	5	6
Discuss						
1. Prior Value	1.00					
2. Prior Positivity	0.33*	1.00				
3. Prior Participation	-0.40*	0.05	1.00			
4. Value	0.48*	0.21*	-0.51*	1.00		
5. Positivity	0.17	-0.05	-0.32*	0.65*	1.00	
6. Participation	0.13	-0.13	-0.40*	0.56*	0.71*	1.00

Note: * $p<0.001$

Finally, the results for “Discuss” (interactive) were significant for all three student response constructs. Much like the active type of instruction, participation in the prior course was negatively associated with value (-0.51), positivity (-0.32), and participation (-0.40) in the current course, with two of the three relationships being moderate, suggesting that lower reports of participation in prior courses were associated with higher reports of value, positivity, and participation in the current course, and vice-versa, for this type of instruction. Furthermore, value in the current course was found to have a significant positive relationship with value (0.48) and positivity (0.21) in the prior course.

Questions still remain, however, in understanding how each of these groups of variables impact students' overall evaluation of the course and instructor. In the next section, I discuss the results of the hierarchical multiple regression model, which estimates the effect of each of these groups of variables (prior response, current response, and the frequency with which these four types of instruction are perceived to be used in the classroom) on the evaluation construct.

Models Examining the Relationship between Prior and Current Student Response

The third part of Research Question 3 addresses the relationships between prior and current student response to each type of instruction, the frequency with which students perceived the instruction was used in the current course, and how students subsequently evaluated their current course and instructor. I also included several control variables, such as student demographics and grade information, in my analyses to ensure that these relationships were not associated with other mitigating factors outside of these variables of interest. In order to better understand these relationships, I estimated the relationships between prior and current student response and the frequency of use for each of the four types of instruction on students' overall evaluation of the course and instructor using a hierarchical multiple regression model. I used the hierarchical multiple regression approach, adding five groups of variables in sequential steps, in order to determine which groups of variables explained the most amount of variance in the dependent variable (the evaluation construct). These groups of variables are illustrated in Figure

8.

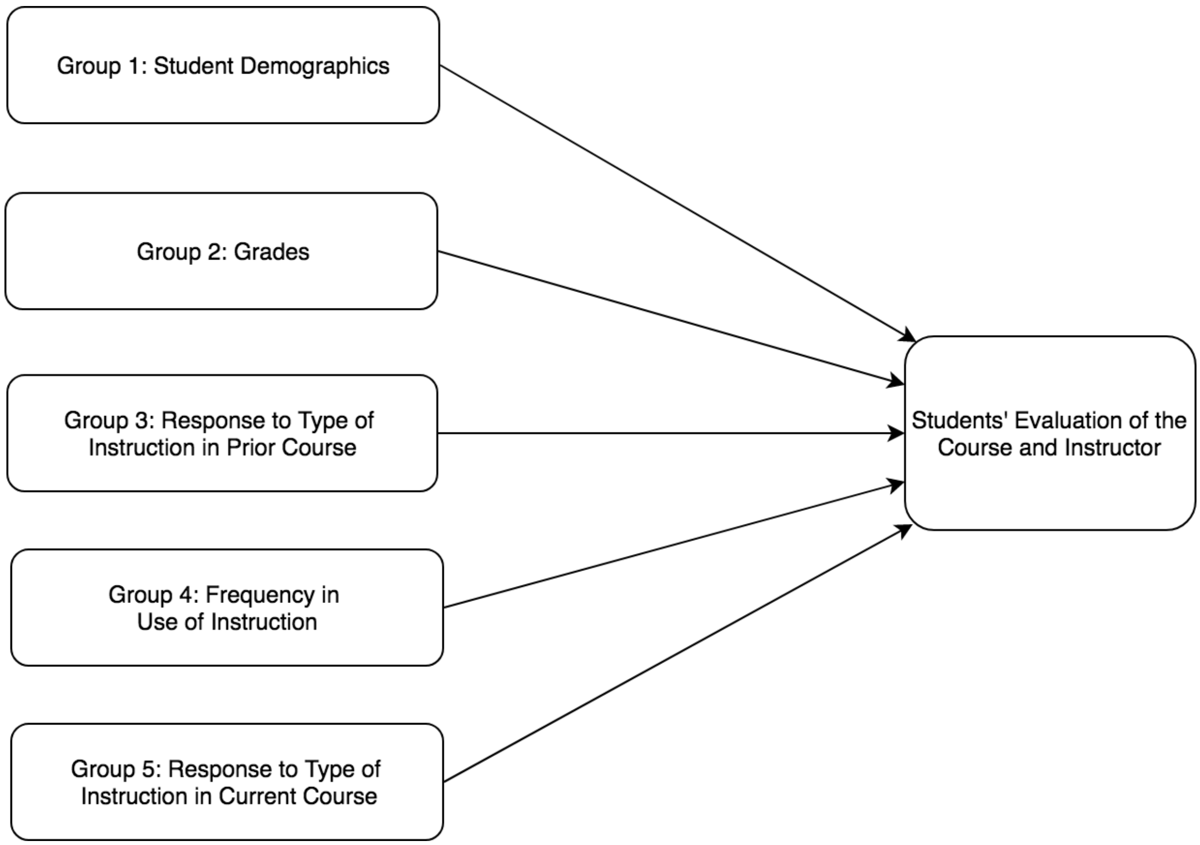

Figure 8. Illustration of the five groups of variables added to the hierarchical multiple regression model on students' evaluation of the course and instructor.

As discussed in Chapter 3, the blocks of variables (in the order they were added to the model) included: 1) student demographics (year in college, gender, race/ethnicity, and citizenship); 2) grades (students' current GPA and expected grades in the course); 3) student response to the use of each of the four types of instruction in their prior course; 4) the frequency with which each type of instruction was perceived to be used in the current course, and; 5) student response to the use of each of the four types of instruction in their current course.

Regression Diagnostic Tests. I conducted a series of regression diagnostic tests on my full model which included all of the variables. First, I checked for any data that might have unusual or influential effect on the results of my regression analysis. I checked for outliers, leverage points, and influential variables using DFITS, DFBETA (Besley, Kuh, & Welsch, 1980), and Cook's distance (Cook, 1977) measurements. All DFITS measurements were less than 0.016 (4/n), all Cook's distance measurements were less than 0.8 (2 x $\sqrt{k/n}$). For the DFBETA measurements, only two observations exceeded the "rule of thumb" of 0.13 (2/$\sqrt{n}$) on the same two variables (positivity about and participation in "listening to the instructor lecture"). Both of these observations were Latino/a students who scored these response variables about two standard deviations below the mean for all eight Latino/a students in the sample. Given that this subsample was so small, this likely influenced the overall relationship of the Latino/a variable on evaluation; however, this variable was non-significant in the final model, so I choose to keep these observations in my final model.

Second, I tested the normality and homoscedasticity of the residuals in my model to assure the validity of all test statistics (t-tests and F-tests). I tested the normality visually using kernel density and standardized normal probability plots, and I tested for heteroscedasticity using Cameron and Trivedi's (1990) information matrix test ($\chi^2(242) = 242.00; p = 0.47$) and Breusch-Pagan's (1979) / Cook-Weisberg's (1983) test for heteroscedasticity ($\chi^2(39) = 44.21; p = 0.26$). I also tested the normality of the population using the Shapiro-Wilk normality test, which produced a non-significant statistic (p=0.12) indicating that I could not reject the null hypothesis that the sample comes from a population that has a normal distribution.

Third, I tested for multicollinearity using a variance inflation factors (VIF) test. None of the variables in the final model had a VIF above 2.5, and the mean VIF was well below 1.0, suggesting no issues with multicollinearity. To further test for issues of multicollinearity, I estimated several other regression models with each of the prior and current student response variables excluded from the analysis and found no unexpected patterns or significant changes in coefficients.

Finally, I tested for model specification and omitted variable bias using the link test of model specification (Pregibon, 1980) and the Ramsey (1969) regression specification-error test (RESET) for omitted variables. All tests were non-significant, indicating a failure to reject the assumption that the model is specified correctly and has no omitted variables. With regards to the findings of the Ramsey RESET test, this is not to say that there is a causal relationship between the independent and dependent variables or that no influential variables might have been left out of this model, but rather that there were no non-linear combinations of the explanatory variables that might have improved the explanatory power (variance explained) of the model.

Model Building and Coefficients. I estimated a five-stage hierarchical multiple regression model with students' overall evaluation of the course and instruction (evaluation) as the dependent variable. The results of this analysis are presented in Table 17. Student demographics were entered in the first block of variables. These variables contributed significantly to the model (F (9, 232) = 2.42, $p<0.05$) and were found to explain approximately 9% of the variation in evaluation. Next, grade information was added to the model, which only explained an additional 2% of the variation in evaluation and did not have a significant impact on the overall model (F (2, 230) = 0.19, $p=0.08$). Students' response to each of the four types of instruction in their prior course was added in the third block of variables. These variables explained an additional 15% of the variation in evaluation and had a highly significant impact on the model (F (12, 218) = 9.12, $p<0.001$). Next, I added the frequency with which each of the four types of instruction were perceived to be used in the current course, explaining another 4% of the variation in evaluation and significantly improving the model (F (4, 214) = 6.02, $p<0.001$). Finally, I added students' response to each of the four types of instruction in the current course to the model. These variables explained an additional 24% of the variation in evaluation and also significantly improved the model (F (12, 202) = 17.69, $p<0.001$). Together, the five blocks of variables explained 53% of the variance in the evaluation construct.

In the final model, none of the variables in the student demographics or grade information blocks were significantly associated with the evaluation construct. Among the prior student response variables, only two variables, value and participation of “Listen,” were found to be significantly associated with students’ evaluation of the course and instruction. A one standard deviation increase in value of “Listen” was associated with a 0.201 standard deviation increase in evaluation ($p<0.001$), while a one standard deviation increase in participation (that is, engaging in listening during lecture) was associated with a 0.257 standard deviation increase in evaluation ($p<0.001$).

The frequency with which each of the four types of instruction were perceived to be used in the current course were associated with increases in evaluation. Two of these four types of instruction were associated with larger increases: a one standard deviation increase in the reported use of “Answer Q’s” and “Brainstorm” were each associated with 0.20 and 0.19 standard deviation increases in evaluation, respectively ($p<0.001$). The associations between the reported use of “Listen” and “Discuss” were slightly smaller, with a one standard deviation increase in the reported use of each of these types of instruction being associated with 0.12 and 0.10 standard deviation increases in evaluation ($p<0.001$), respectively.

Among the current student response variables – the block of variables that explained the most amount of variation in evaluation – six of the twelve variables had a significant positive association with evaluation, including student response to three of the four types of instruction (“Answer Q’s,” “Brainstorm,” and “Discuss”). Each one standard deviation increase in the reported value of “Answer Q’s” was associated with a 0.198 standard deviation increase in

Table 17

Hierarchical Multiple Regression of the Relationship Between Variables and Students' Evaluation of their Course and Instructor.

			B	SE		B	SE		B	SE		B	SE		B	SE	
Group 1: Demographics		Female	-0.100	0.066		-0.101	0.066		-0.096	0.068		-0.074	0.065		0.009	0.033	
		Race (vs. White)															
		Asian-Pacific Islander	0.053	0.087		0.048	0.086		0.038	0.090		-0.005	0.087		-0.017	0.044	
		African-American	0.038	0.155		0.018	0.159		0.036	0.164		-0.010	0.157		-0.044	0.079	
		Latino/a	0.056	0.181		0.062	0.181		0.044	0.188		0.035	0.180		-0.033	0.091	
		Multiracial	-0.017	0.100		-0.016	0.099		0.003	0.100		-0.006	0.098		0.012	0.050	
		Class (vs. First-Year)															
		Sophomore	0.212	0.077	**	0.184	0.078	*	0.188	0.080	*	0.128	0.077		0.016	0.040	
		Junior	0.250	0.098	***	0.211	0.102	**	0.181	0.107	*	0.069	0.105		-0.038	0.055	
		Senior	-0.028	0.294		-0.034	0.292		-0.026	0.297		-0.009	0.284		-0.007	0.143	
		U.S. Citizen	-0.105	0.123		-0.094	0.123		-0.064	0.127		0.008	0.122		0.011	0.062	
Group 2: Grades		Expected Grade				-0.135	0.047	*	-0.126	0.048	*	-0.139	0.045	*	0.024	0.023	
		GPA				0.109	0.051		0.095	0.054		0.113	0.051		0.023	0.026	
Group 3: Response to Type of Instruction in Prior Course	Listen	Value							0.237	0.031	***	0.216	0.054	***	0.201	0.030	***
		Positivity							-0.048	0.071		-0.101	0.068		-0.105	0.037	
		Participation							0.274	0.041	***	0.260	0.060	***	0.257	0.031	***
	Answer Q's	Value							0.012	0.071		0.016	0.068		-0.046	0.036	
		Positivity							0.049	0.089		0.070	0.085		0.084	0.046	
		Participation							-0.034	0.066		-0.080	0.065		-0.100	0.035	
	Brainstorm	Value							0.040	0.079		0.032	0.076		0.033	0.039	
		Positivity							0.026	0.099		-0.076	0.096		-0.046	0.048	
		Participation							-0.094	0.086		-0.064	0.082		0.022	0.041	
	Discuss	Value							-0.021	0.060		-0.043	0.057		-0.009	0.030	
		Positivity							-0.072	0.082		-0.030	0.078		-0.033	0.042	
		Participation							0.074	0.072		0.052	0.069		-0.019	0.035	
Group 4: Frequency in Use of Instruction		Listen										0.217	0.045	***	0.115	0.025	***
		Answer Q's										0.194	0.031	***	0.195	0.016	***
		Brainstorm										0.139	0.032	*	0.187	0.017	***
		Discuss										0.096	0.030	***	0.095	0.028	***
Group 5: Response to Type of Instruction in Current Course	Listen	Value													0.022	0.027	
		Positivity													0.028	0.027	
		Participation													0.041	0.034	
	Answer Q's	Value													0.198	0.029	***
		Positivity													-0.029	0.034	
		Participation													0.193	0.036	***
	Brainstorm	Value													0.260	0.031	***
		Positivity													0.016	0.035	
		Participation													0.135	0.028	***
	Discuss	Value													0.102	0.027	**

Positivity					0.149	0.039	***
Participation					0.069	0.034	
R-Squared	0.09	0.11	0.25	0.29	0.53		
Delta R-Squared	0.09	0.02	0.15	0.04	0.24		
F Statistic	2.42*	2.61**	11.73***	17.75***	35.44***		
Delta F Statistic	2.42*	0.19	9.12***	6.02***	17.69***		

Note: All standard errors were clustered by students' current courses; * p<0.05; **p<0.01; ***p<0.001

evaluation ($p<0.001$). Similarly, one standard deviation increases in the reported values of "Brainstorm" and "Discuss" were associated with 0.260 ($p<0.001$) and 0.102 ($p<0.01$) standard deviation increases in evaluation, respectively. Reported participation was positively associated with increases in evaluation for "Answer Q's" ($\beta = 0.193$; $p<0.001$) and "Brainstorm" ($\beta = 0.135$; $p<0.001$), while reported positivity was positively associated with increases in evaluation for "Discuss" ($\beta = 0.149$; $p<0.001$). "Listen," which was the only one of the four types of instruction with significant findings for the prior student response variables, had no significant associations between current student response and evaluation. These findings suggest that how students felt/responded about the passive instruction before the course had a connection with evaluation, while how they felt/responded to the three more active forms of learning in the current course were associated with evaluation.

Summary for Changes Between Prior and Current Student Response

Turning back to Research Question 3 ("What relationships exist between prior response, current response, the frequency with which each type of instruction is used, and how students subsequently evaluate the course and instructor?"), the results from the analyses for this section offer a few key takeaways. First, based on the results from the dependent t-test for paired samples, students' responses to each of these four types of instruction appeared to change between the beginning and end of the semester. Specifically, responses for value of the passive, active, and constructive types of instruction decreased between Survey 1 and Survey 2, while positivity for the active, constructive, and interactive, and participation in the active and constructive types of instruction increased. Second, student response to one type of instruction does not necessarily correlate to the same type of response for any of the other three types of instruction. This is reflected in the Pearson's correlation coefficients, which suggested only moderate relationships between response variables within each type of instruction. Furthermore, these relationships do not necessarily extend to prior and current response within the same type of instruction, as a majority of the relationships between prior and current response constructs were weak and non-significant. There were some notable exceptions, however, such as the relationship between students' prior value, positivity, and participation, and their value response in the current course.

Finally, the results of the hierarchical multiple regression model offer some interesting findings. For example, none of the demographic variables were associated with changes in students' evaluation of the course, nor were either of the GPA and expected grade variables. Furthermore, when examining the variables of interest for this research study – prior and current student response and the frequency with which each type of instruction was reportedly used in the course – I found that the frequency in the use of each type of instruction was positively associated with increases in evaluation of the course and instruction. For the response constructs, only prior student response to the passive type of instruction ("Listen") had a significant relationship with evaluation. This is in contrast to the results for current student response, where the active, constructive, and interactive types of instruction had a positive association with evaluation. Additionally, across each of the significant groups of findings for both prior and current student response, value had a consistent positive association with evaluation, suggesting that this was the more reliable of the three types of responses.

Chapter Summary

In this section, I explored the following three research questions and their sub-questions:

1. What types of instruction are being used in introductory engineering courses at a large research university?

   a. Do these types of instruction vary by class/instructor?
2. How do students respond to different kinds of instruction in these courses? How does their previous experience with different kinds of instruction influence their response to its use in their current course?
   a. Do these responses vary by the class in which they are currently enrolled?
3. What relationships exist between prior response, current response, the frequency with which each type of instruction is used in the current course, and how students subsequently evaluate the course and instructor?
   a. How does student response to each type of instruction change between prior and current courses?
   b. Does student response to one type of instruction correlate with the student response to any of the three other types of instruction? Furthermore, does prior student response correlate with current student response?
   c. How might prior and current student response to each type of instruction and the frequency with which the type of instruction is used in the current course impact students' overall evaluation of the course and instructor?

I found that the types of instruction most commonly-used were a mix of different types from each of the ICAP classifications. Although passive types of instruction were used most often, students reported experiencing many constructive types of instruction nearly as frequently. Furthermore, interactive types of instruction were used between *seldom* and *sometimes* (mean = 2.59) and active types of instruction were used *seldom* (mean = 2.28).

For the response to these types of instruction, in both current and prior courses, students indicated similar responses for positivity and participation across all four types of instruction.

For value, however, students reported a significantly lower ($p<0.001$) mean for interactive types of instruction as they only *seldom* valued the activity. Finally, several significant relationships were discussed in the linear regression models, with students' *prior* responses to the passive type of instruction having a positive relationship with evaluation, while students' *current* responses to the active, constructive, and interactive types of instruction had a positive relationship with evaluation. Furthermore, frequency in reported use of each type of instruction was positively associated with students' evaluation of the course and instructor. In the next chapter, I discuss the findings from the qualitative portion of this research study, and more specifically, explain how students felt about these types of instruction in their current course. This chapter will help me to explain why students respond in the ways that they do to each of these types of instruction.

Chapter 5: Qualitative Results

In Chapter 5, I present the results of my qualitative analysis of the five focus groups conducted with 20 students who completed Survey 1 and volunteered to participate in this focus group. These focus groups were conducted during the 12th week of the semester (coinciding with the implementation of Survey 2) in order to capture students' experiences in their current courses at the end of the semester. A numbered list of the participants, as well as their gender, major, and the course in which they were enrolled for this study are provided in Table 18.

Table 18.
Listing of Focus Group Participants

Participant	Gender	Major	Course
1	Female	Biomedical Engineering	BIOMEDE 231
2	Female	Biomedical Engineering	BIOMEDE 231
3	Male	Biomedical Engineering	BIOMEDE 231
4	Male	Biomedical Engineering	BIOMEDE 231
5	Female	Chemical Engineering	CHE 330
6	Female	Chemical Engineering	CHE 330
7	Male	Chemical Engineering	CHE 330
8	Male	Chemical Engineering	CHE 330
9	Male	Computer Engineering	EECS 215
10	Female	Electrical Engineering	EECS 215
11	Male	Electrical Engineering	EECS 215
12	Male	Electrical Engineering	EECS 215
13	Male	Computer Engineering	EECS 280
14	Male	Data Science	EECS 280
15	Male	Data Science	EECS 280
16	Female	Electrical Engineering	EECS 280
17	Female	Mechanical Engineering	EECS 280
18	Male	Aerospace Engineering	MECHENG 211
19	Male	Mechanical Engineering	MECHENG 211
20	Male	Mechanical Engineering	MECHENG 211

The purpose of the focus groups was to better understand this relationship between student response and each type of instruction students encountered in their classrooms. Note that, unlike several analyses in the quantitative section of Chapter 4 that focused on four of the most commonly-used types of instruction, I allowed students to discuss each of the 21 types of instruction they encountered in their courses (as listed in Table 3). Thus, I use the qualitative results from this study to further investigate the second research question in this study:

1. How do students respond to different kinds of instruction in these courses? How does their previous experience with different kinds of instruction influence their response to its use in their current course?

Specifically, I use these focus groups to better understand why students respond in positive or negative ways to each of the different types of instruction encountered in their current courses.

I used directed content analysis to analyze the data from these focus groups. Based on the prior theories about types of instruction and student response introduced in Chapter 2, I set out with an initial framework (Figure 4) that laid the foundation for the structure of the focus group protocol. I asked students about how they typically responded to different types of instruction used in their courses. I also offered students an opportunity to share their thoughts on other factors that might help explain their response to these types of instruction. In analyzing these focus group data, I first reviewed the transcripts and flagged instances where students discussed how they responded to the various types of instruction encountered in their courses. Then, I coded responses by the type of instruction the student was discussing (e.g., passive, active, constructive, and interactive) and within each of the four types of instruction, I created a set of codes that characterized the themes that emerged. Thus, the themes within each type of instruction emerged exclusively from students' discussion of that type of instruction.

After I coded each of these themes individually, I examined them across each of the four types of instruction to explore commonalities. The codebook I developed for my analysis of the focus groups is provided in Table 19. If themes were closely aligned across types of instruction, I refined the name of the themes to reflect that cohesion across types of instruction. For example,

Table 19.
Codebook for Directed Content Analysis of Focus Groups

Type of Instruction/*Themes*	Description (Number of Students Mentioning)
Passive	
Understanding Expectations of Lecture	Students describe a lack of change in how instructors approach lecture-oriented (passive) activities in the classroom. Students often find value in this because they know what to expect from passive instruction, but this can also be monotonous and lead to disengagement. (20 out of 20)
Seeing Utility for Engineering Career	Students find value in passive types of instruction because of their utility in preparing them for their career as an engineer. (12 out of 20)
Being Prepared for the Exam	Students value many passive types of instruction because they understand what is expected of them (and what they need to study for) on exams and other graded assignments. (8 out of 20)
Active	
Experiencing Good Instructor Implementation of Activities	Students feel that the success or failure of this type of instruction is dependent upon how well the instructor sets up an activity and offers support during its implementation. (11 out of 20)
Seeing Utility for Engineering Career	Since active types of instruction often involve solving problems individually that they would encounter in their careers, students value these activities and are more likely to participate as these activities help increase their confidence in doing the work of an engineer. (8 out of 20)
Experiencing Novelty of the Material	The level of familiarity of the content being used in the type of instruction is a deciding factor as to whether or not students will participate. (6 out of 20)
Constructive	
Experiencing Good Instructor Implementation of Activities	Students feel that the success or failure of this type of instruction is dependent upon how well the instructor sets up an activity and offers support during its implementation. (11 out of 20)
Seeing Utility for Engineering Career	Since constructive types of instruction often involve ill-structured problems that they would encounter in their careers, students value these activities and are more likely to participate as these activities help increase their confidence in doing the work of an engineer. (8 out of 20)
Interactive	
Perceiving Inconsistent Contributions	Students describe incongruences in workload responsibilities or quality of work between themselves and other group members that may impact how much they value interactive types of instruction or how positively they feel about the work. (11 out of 20)
Self-Selecting Group Members	Students describe that being able to select peers for group-oriented work was a very positive experience, while experiences with randomly assigned groups were mixed. (6 out of 20)
Experiencing Good Instructor Implementation of Activities	Students feel that the success or failure of this type of instruction is dependent upon how well the instructor sets up an activity and offers support during its implementation. (5 out of 20)
Seeing Utility for Engineering Career	Students find value in interactive types of instruction because of their utility in preparing them to work in groups with diverse individuals in engineering. (3 out of 20)

the theme “instructor implementation of activities” was present across active, constructive, and interactive types of instruction and “utility for engineering career” emerged in all four types of instruction. These types of instruction, and the themes within each type, are discussed at length in the sections that follow. As noted in Chapter 2 and in alignment with Chapter 4, these types of instruction are presented here and throughout this chapter in reverse from the order in which they appear in the acronym (PACI rather than ICAP) to highlight the increasing levels of student participation that should result when moving from the passive (lowest) to the interactive (highest) approach.

Passive Types of Instruction

Students in all of the focus groups felt that passive types of instruction were the most common form of instruction in their current courses. These passive types of instruction included: “listen to the instructor lecture during class (Listen),” “watch the instructor demonstrate how to solve problems,” and “get most of the information needed to solve the homework directly from the instructor.” Based on students’ comments about why they responded in the ways they did, three themes emerged regarding student response to passive types of instruction: understanding expectations of lecture, seeing utility for engineering career, and being prepared for the exam.

Understanding Expectations of Lecture

Students in each of the five focus groups indicated that they had experienced varying forms of passive instruction in prior courses that ranged from observing the instructor lecture by means of chalkboard or PowerPoint presentation to watching the instructor demonstrate how to solve various problems used for homework and/or exam questions. Despite differences in the medium used to disseminate course concepts (e.g., chalkboard, overhead projector, and PowerPoint), all twenty students shared that these experiences were similar from course-to-course, and that the consistency in understanding what was expected of them from course-to-course was often a benefit of passive instruction. In other words, students understood their role in this type of instruction and how it would impact their overall grade in the course (e.g., concepts discussed during lecture were linked to exam questions which were linked to overall course grades).

For example, one student shared his rationale for preferring passive types of instruction over more active ones:

> *If [an instructor] is lecturing, I always know what's expected of me. I sit down to watch [the instructor] do problems. I know those problems are probably going to appear on the homework or an exam…. I'm not worrying about, "am I going to get put into a group project where I do a majority of the work" or "am I going to do a problem incorrectly during class and waste fifteen minutes of my time."* (Participant #12, Male, Electrical Engineering Major)

Another student equated this to having a "safe place" that helped to alleviate some anxiety from other, more active, types of instruction:

> *I'm not saying all group work is bad…. I just think sometimes it's nice when the instructor lectures because you can "let your guard down." It requires less effort from me, it's my "safe space" or my "comfort blanket" – whatever you want to call it.* (Participant #7, Male, Chemical Engineering Major)

Note that both of these students were anxious about the unpredictability of more active types of instruction. For example, these students knew what was "expected of them" from listening to lecture, whereas that might not be the case for active, constructive, or interactive types of instruction. In the latter quote, the student shared that he did not dislike more active types of instruction, like group work; sometimes he wanted to put in less effort, and it was helpful to watch an instructor lecture or work problems because there was less expected of him and he could "let his guard down."

Just as some students deemed the clarity of expectations from lecture as a *benefit* of passive types of instruction because it provided a break between more active types of instruction, students also shared that consistent lecture often elicited negative responses from them. For example, all of the students shared that they had attended a course previously where the type of instruction was entirely lecture-based and that these courses were difficult to find a purpose for attending since they could receive the same material through means outside of class. For example, one student shared her experience with a two-hour course where the instructor lectured the entire time:

> *One professor in particular, it was very much just lecture-based. He would throw a few words on a slide with photos and he would just talk the entire time. It was a two-hour long lecture. That class was also two hours, and [my current course] is two hours…. Just about every day [the lecture course] seemed more of like a chore to go to class because I would be listening to a lecture and I'd just be thinking to myself, "I'm not really getting much more out of this than I would looking through a textbook and just watching videos on YouTube. I can do that anywhere…. This isn't making me a better engineer."*
> (Participant #10, Female, Electrical Engineering Major)

In fact, students shared that prior negative experiences regarding lecture (e.g., boredom or lack of interest) would often impact how they approached lecture-oriented courses in the future. Students agreed that negative prior expectations regarding lecture often impacted how "engaged" they were when participating in courses that featured mostly passive types of instruction. One student commented:

> *I can't not take the course. But, if it's between [this course] and [another course I'm interested in], I'm probably going to put most of my effort into the other course [with more active types of instruction]…. [Q: What if the lecture course was a course you were interested in?]… I guess I'd have to realign my interests? I don't know. Even if I like the material, it's almost painful [to sit and watch the instructor lecture] …. I'm not excited about being in that class.* (Participant #3, Male, Biomedical Engineering Major).

Another student shared a similar experience with an instructor who exclusively used lecture in his course and described how he responded when he encountered a later course that was set up similarly:

> *I did have that feeling again, "Oh my gosh. It's one of those professors." … [Lecture] just doesn't grab my attention…. Of course, I wanted to put in a lot more effort, but sometimes I just didn't have the heart to sit through another lecture. I just wanted something else, anything else, besides lecture…. So, sometimes I would just skip.... I know what I'm getting out of that lecture.* (Participant #19, Male, Mechanical Engineering Major)

Another student in the same focus group agreed:

> *It became a bit of a chore. Whenever I was pressed for time to get other assignments or anything done, the class that I would knock out first if I had to skip a class was going to be that basic lecture. It was not going to be the class that I actually really learned while I was in that room.* (Participant #9, Male, Computer Engineering Major)

These negative responses appeared to be in context to the fact that students had all taken some courses where the type of instruction was purely lecture and other courses where more active types of instruction had been included in the curriculum, and thus they were able to see the benefits of breaking up the monotonous expectations of lecture in a course and were reluctant to participate in courses where the instructor exclusively lectured. In other words, prior experiences with lecture did impact how they approached passive types of instruction in future experiences.

Seeing Utility for Engineering Career

Some students shared that passive types of instruction were also useful for their engineering career (i.e., becoming a successful engineer). Twelve students indicated that they found it more useful when instructors focused on teaching the material that students needed to know for a career in engineering. Students used this as a rationale for claiming that more active forms of learning were sometimes not as useful to them. For example, one student juxtaposed watching an instructor lecture versus discussing concepts with other classmates during class:

> *So my thought is, I want to know what's useful to be a good engineer. And, no offense to my neighbor, but he doesn't know that. And, really, neither do I. The instructor does….Yeah, I don't really enjoy talking [about concepts] with classmates. That isn't going to teach me how to be an engineer. An engineer knows their stuff, and I'd much rather be knowledgeable about the facts, not sit and try to explain it to another classmate.* (Participant #8, Male, Chemical Engineering Student)

In this example, if given the choice, the student would rather listen to the instructor lecture because he felt this was the most valuable for understanding how to become a successful engineer in his field. He did not feel that talking with a classmate about concepts during class was useful for him or his career goals. But, he could be misunderstanding the purpose of discussing concepts with other classmates during class, which can be used as a way to confirm that the student knows and is comfortable with describing the material.

Other students shared similar issues with types of instruction that they did not feel were practical in becoming an engineer. Again, students were often comparing passive and more active approaches for the utility of each type of instruction. Some felt this was based on the "time-crunch" of taking multiple courses in a semester and only having so much time to dedicate to learning the material:

> *In the grand scheme of things, we're taking anywhere from 14 to 18 semester hours…so I have 3-4 other courses to think about and I can't give all of myself to all of these classes. When I'm making the decision about what's helpful to me… I want to know what I need to know… What do I need to know for my internship or my job…. And hopefully the instructor knows that.* (Participant #20, Male, Mechanical Engineering Major)

In this example, the student shared that he felt he only had so much time and effort to give for each class (i.e., "*I can't give all of myself to all of these classes*"), and when given the choice between passive types of instruction and more active ones, he preferred the passive ones because he thought the instructor would disseminate what the student would "*need to know*" for a future internship or job. Others echoed similar concerns about the purpose of the courses needed for their degree and what they expected out of them, as one student said more bluntly: "*I'm not paying money to do group projects. Just tell me what I need to know to be a successful engineer*" (Participant #11, Male, Electrical Engineering Major).

In this preceding quote, this student was very direct about only concerning himself with the material he needed to know as an engineer, and across all of the quotes in this section, students believed that they could learn to be an engineer just by listening to the instructor and reading the course materials. They did not believe that complex interactions, such as interacting with others, or analyzing and evaluating ill-structured problems were beneficial for their learning process. This finding represents a very narrow view of what it takes to be a successful engineer and has implications as engineering faculty should explicitly state the benefits and purpose of each types of instruction (especially these more active forms) at the beginning of each activity.

Being Prepared for the Exam

Similar to the preceding responses about the expectations from lecture, eight students shared that they enjoyed many passive types of instruction because they knew they could directly link what was covered in class to preparing for exam problems. In fact, all of the comments in this theme were positive: students suggested that they appreciated it when instructors provided them with useful material for a graded assignment and/or explained the steps taken to work through a problem that might be featured on an exam. Students agreed that seeing an instructor demonstrate how to work a problem was the most helpful aspect of passive types of instruction. One student commented:

> *I'd say the instructor solving problems was essential for me.... When it came to the exam you'd have a formula sheet, but the formula sheet's not useful if you don't know how to use it and you don't know how to go about solving these problems and stuff.... It's so much more helpful than trying to figure out the problem myself.* (Participant #17, Female, Mechanical Engineering Major)

The act of watching the instructor solve the problem through passive instruction was "essential" to this student's success on exams because the instructor taught the class how to apply formulas to the problems sets that they were given. This same student commented that working through the problem sets by herself was not as helpful because she would not know whether or not she was doing the problem correctly by the time the exam was administered:

> *So I do think it was better for [the instructor] to show me a little bit, how to do it, rather*

than just leaving me by myself to do it. I don't learn anything from just struggling through the problem. I get frustrated and quit…. And, then, that's not really useful when I have to take a test. (Participant #17, Female, Mechanical Engineering Major)

Another student in the same focus group shared a similar viewpoint:

I really appreciate seeing how to solve problems and giving examples. I know that there are some professors, and I don't think I've had any especially like in engineering, but there's some professors who have the belief that you should not necessarily show how to solve problems and let students figure it out on their own. I like the guidance to some extent. I like it when the instructor shows how to solve a specific problem…. I do appreciate it when instructors demonstrate and go through the entire problem and not just like put stuff up there but actually go through it on their own….I feel more confident when I'm taking the final. (Participant #8, Male, Chemical Engineering Major)

As these quotes illustrate when these students were unfamiliar with the material or with how to solve a problem, they preferred more passive types of instruction to help guide them through the problem-solving process. Rather than putting in the effort to learn new material or solve problems on their own or when working in groups, they could learn the answers directly from the instructor:

"And you know you have the right answer to [a problem set or concept], because you saw them do it or they told you what you needed to know. So it's good to have ... You know you have the right answer [to an exam]." (Participant #8, Male, Chemical Engineering Major)

Summary of Responses to Passive Types of Instruction

Across each of these three themes, student responses could be categorized into one of two groups regarding their response to passive types of instruction. The first group consisted of seven students (Participants 4, 7, 8, 11, 12, 14, and 20). In this group, students thought positively about passives types of instruction because those types of instruction provided students with the knowledge they would need, both in the short-term (knowledge needed for exams) and the long-term (knowledge needed as an engineer in the field). Members of this group also indicated that they felt positively about passive types of instruction because they understood and felt comfortable with what would be expected of them in this type of instruction. They stated that they knew little would be expected of them and that they could sit back and receive knowledge with little effort needed on their end. It appeared that this group of students was comfortable with lecture, and that in many instances, the thought of trying something "new" (in an active learning sense) would be a challenge. This finding could also be attributed to a very grade-centered view of learning in the engineering environment, especially concerning what students needed to know for an exam. In other words, they knew they wanted to get a good grade on an exam, the instructor had the answers and would tell them what to know for the exam, leading to a passing grade in the course and moving to the next course in the sequence. But, these students did not seem to look beyond the application of this material to this specific course and think about how the skills they were developing – especially those gained from more active types of instruction, such as determining the answers to complex problems on their own or working together with others to achieve a task – might benefit them as engineers.

The second group consisted of five students (Participants 1, 3, 9, 10, and 19). In the second group, students moved beyond just seeking out lecture for knowledge and felt negatively about this type of instruction *when used in excess*. Note that these students understood the benefit of passive types of instruction for introducing core concepts, but felt negatively when this was the predominant method used for the dissemination of knowledge because they believed that the engineer needed to “do” rather than just “know” the material. In other words, these students had moved beyond using an instructor as a sole source of knowledge and began discovering their role in this learning process. In this group, students often disconnected themselves from the lecture if used excessively – opting to do other tasks, like finish homework assignments for this or another course – or sometimes skipping the lecture entirely. As noted in subsequent sections in this chapter, these students preferred more active types of instruction (e.g., active, constructive, and interactive) intertwined in these class sessions.

Active Types of Instruction

Students in each of the focus groups indicated that active types of instruction were also used often in their current courses; however, students shared that the specific type of instruction encountered and the frequency with which each type was used differed from course to course. These active types of instruction included: “make individual presentations to the class,” “be graded on my class participation,” “solve problems individually during class,” “answer questions posed by the instructor during class (Answer Q’s),” “ask the instructor questions during class,” and “preview concepts before class by reading, watching videos, etc.” Based on students’ comments, the following three themes emerged regarding student response to active types of instruction: experiencing good instructor implementation of activities, seeing utility for engineering career, and experiencing novelty of the material.

Experiencing Good Instructor Implementation of Activities

Students felt that the success or failure in the use of active types of instruction was dependent upon how well the instructor set up an activity and offered support during its implementation. Note that this theme was exclusively discussed in context to solving problems individually during class. For example, eleven students shared that they had a frustrating experience with solving a problem individually during class because they felt they were not given the proper tools to prepare them to successfully complete the activity. One student expressed his frustration with doing problems individually in the course, because he had not been taught how to work the problems beforehand and was not given support to help him through the process:

> *I honestly felt like sometimes it was a waste of class time because he gave us quite a bit of time to work on a problem [by ourselves]. And honestly sometimes the problem was really hard and you just kind of get stuck. And then you just have the rest of that time where you're not really doing anything because you don't know how to proceed with the problem. And he wasn't providing us with any help while we were working on it. So then you have to wait until he gives you a solution. So, in that sense it might not have been the best use of class time.* (Participant #18, Male, Aerospace Engineering Major)

Another student in a different focus group shared that he already felt lost at the beginning of class because he did not understand the course concepts from reading the night before, and the instructor immediately started class by having them solve a problem individually:

> *On my own, I would get lost on some things, just because I wasn't quite sure on what was happening, because I didn't get the book concepts that well the night before…. So, I*

would just sit there and pretend like I knew what I was doing [during the activity]. (Participant #12, Male, Electrical Engineering Major)

Furthermore, these students felt that individual problems were not helpful because they did not help them prepare for their homework or exams:

> *[The instructor] would have us do a lot of problems [by ourselves]… but the problems weren't connected to the homework. We would struggle a lot with the homework. Sometimes she would ask us to do proofs as well. We were like, "Oh, how do we do it because you haven't really taught us anything like that?"… And we'd get to the exams and the questions were ridiculously harder than what we did in class. So, I'm wondering why I put in the effort to do those problems [during class] if it doesn't even help me on the exam.* (Participant #2, Female, Biomedical Engineering Major)

In addition to having the material or knowledge needed to succeed, students felt that having the appropriate amount of time to work on a problem was also essential:

> *And, so when you have a very short 50 minute period to do both the conceptual [work] and trying to get through some, like how these equations relate to a real-life situation through a problem set, it's a little bit time rushed and crunched. You've left feeling a little bit unsatisfied with what you've done…. It's like, pick one or the other. Whatever helps me succeed rather than trying to cram it all in an hour block.* (Participant #20, Male, Mechanical Engineering Major)

The same student later shared that he was less willing to work on a problem for this course in the future because he didn't feel like he would finish the problem set and benefit from the experience: "*So then, [the instructor] did it again in the next class. And I was like, 'forget it.' I'll work on something else*."

Although responses were mostly negative in this theme, students did share instances where active types of instruction were properly prepared and support was received from the instructor:

> *In one of my other previous courses, the problem sets were very helpful. The instructor had this whole process where he'd have us work individually and then later in groups, and he had [teaching assistants] walking around the room, and he encouraged questions…. So, that's what I'm thinking of. That's what I always compare it to… And [my other experiences] don't always add up to this.* (Participant #19, Male, Mechanical Engineering Major)

In fact, these students shared examples when an active type of instruction was properly implemented and supported. In hindsight, they also agreed that they compared this experience to their others, and were frustrated when their expectations were not met. To summarize this, the student went on to say: *"Sometimes, I think [the success of these activities] boils down to teaching. Some have been doing this [type of instruction] awhile, others haven't. For me, it's easy to tell which is which"* (Participant #19, Male, Mechanical Engineering Major).

Seeing Utility for Engineering Career

Much like for passive types of instruction, students shared that active types of instruction were often beneficial because of the utility value in participating in these activities and their future as an engineer. For example, eight students indicated that they appreciated it when their instructor offered opportunities to solve individual problems during class, especially those that featured "real-world problems," because they felt the instructor was actually trying to engage them in the learning process and connect the material to what they might encounter during their careers. One student shared:

> *I have always learned better with real-world examples.... I want to see how [a problem I am solving] connects to what I'm going to do as an engineer…. I learn a lot better when the teacher's using these special examples…and teaching us more of application rather than just giving us lectures on a slide. I was able to learn a lot better from that than I would've just from a general lecture as well…. I know "this is what's expected of me" rather than just "this is what I need to know."* (Participant #10, Female, Electrical Engineering Major)

Another student shared a similar story when her instructor had the class do a problem set individually during class, and then the instructor shared with the class that the problem set was from a specific engineering application:

> *Everyone in the class hears, oh, wow, [this problem] is a real-world example. That's a really cool application... That could be me [as an engineer]. That could be something I'm working on in the future. I feel like that was a very, very, very valuable aspect of the class. That transcends outside of class as well.* (Participant #1, Female, Biomedical Engineering Major)

In both of these instances, the usefulness of active types of instruction was tied to how it helped students think about their career paths and what they would be doing as an engineer.

Students shared that they often preferred active types of instruction to passive ones because this instruction was less about watching an instructor do a problem set and more about applying the knowledge, as they would have to do in a professional situation. One student shared his rationale:

> *A lot of times, if it's not like a tricky concept, I can just watch it once and maybe take some notes to just jog my memory. But I, for me at least, I have to be able to see [the*

problem] and then be able to do [the problem myself]…. If I can't do it here in class, how do I know I can do it out there [in the field]? (Participant #19, Male, Mechanical Engineering Major)

In this example, active types of instruction helped to reinforce the student's learning about the topic and see whether or not he could solve problems on his own, and furthermore, whether or not he actually enjoyed the work he was doing now and would presumably be doing in his internships/future jobs.

Experiencing Novelty of the Material

Six students shared that the level of familiarity of the content to be learned was also a deciding factor as to whether or not they would participate in an activity. If a concept in the class was new to them, students reported that participating in active types of instruction was intimidating because they were concerned about looking unwise in front of their peers. For example, one student indicated that her instructor often tried to get students to ask questions about the material during class, but the material was relatively new to the students. Thus, no one wanted to take the chance to ask a question:

I feel like when you're just learning a new concept, it's very difficult to even ... [the instructor would] stop every five minutes, want us to ask questions to make sure everyone understood it, but when you just learned a concept about five minutes ago, at least personally, there's a point where you don't even know what you don't know, and you don't even know how to ask the question…. He would get blank stares from the class [because]… it takes time and effort to develop a question on a topic that's new to you, especially if you're [asking] it in front of a class, and it can be kind of intimidating…. I don't want to ask a question and everyone else in the class be like 'what an idiot'…. So, *instead, I'd keep my mouth shut…. You don't want to ask a dumb question, but in order to [ask a good question], you really have to put in the effort to learn the material before lecture. It's hard to find time for that.* (Participant #2, Female, Biomedical Engineering Major)

In this example, the student indicated that no one wanted to speak up when the instructor inquired about questions during class because the students believed that they did not fully understand the material. The process of thinking about a question to ask the instructor after a topic was covering in class was inconceivable because "*you don't even know what you don't know"* and the amount of time available to process and think about a question was not available in-class during the activity. Therefore, students would have to study course concepts before they were covered in class, which was not an option because of time restraints. Other students agreed that the difficulty of the material in the course often influenced how they responded to active types of instruction. For example, one student indicated that if the course material was "easy," she would be more likely to participate in the individual problem solving: "*I think it often has to do with the difficulty of the material. So if I find the course content really easy, I wouldn't mind doing [individual problem solving during class] either."* (Participant #17, Female, Mechanical Engineering Major). The implication in the preceding quote is that the course content was easy, so the student was more likely to get the correct solution to the problem, which made the process seem less intimidating.

Summary of Responses to Active Types of Instruction

Across each of these themes, students in these focus groups appeared to fall into one of two groups regarding their response to active types of instruction. The first group consisted of five students (Participants 2, 12, 17, 18, and 20). These students felt negatively about active types of instruction, indicating that the instructor was the ultimate source of knowledge, and whenever they encountered a setback in the process of participating in active types of instruction, they grew frustrated because they felt that the instructor should help them through this process. This phenomenon took place in one of two ways: 1) students were stuck on a certain part of an activity, and rather than try to work through the problem or seek out information in order to work through the problem, they simply stopped participating, or 2) they felt that the material was too new for them to participate in a more active approach to learning. In both instances, however, students did not have the enterprise to move forward with the problem on their own, and they felt it was the instructor's responsibility to make sure that they had this knowledge. It should be noted that there were some cases where students indicated that the instructor could have provided some additional time or support during the activity, and these students felt little initiative to carry on learning past their dedicated class time.

The second group consisted of five students (Participants 1, 5, 9, 10, and 19). In this group, students had discovered that these types of instruction were useful to their skills as an engineer. One explanation is that they understood that they might have to outgrow seeking out the instructor for all knowledge, and put some of the onus on themselves for this process of learning because they would be expected to do so in their careers. As noted in the summary on passive types of instruction, these students understood the purpose of lecture for introducing new topics, but also knew that active types of instruction helped them to be a better engineer in practice, rather than just a knowledgeable student who understood concepts but could not apply them to real-world problems and solutions.

Constructive Types of Instruction

Focus group participants shared several examples where constructive types of instruction were used in their current courses. These constructive types of instruction included: "make and justify assumptions when not enough information is provided," "find additional information not provided by the instructor to complete assignment," "take initiative for identifying what I need to know," "brainstorm different possible solutions to a given problem (Brainstorm)," "assume responsibility for learning material on my own," and "solve problems that have more than one correct answer." Based on students' comments, the following two themes emerged regarding student response to constructive types of instruction: experiencing good instructor implementation of activities and seeing utility for engineering career.

Experiencing Good Instructor Implementation of Activities

As with active types of instruction, eleven students shared that the success of constructive types of instruction was often dependent upon how well the instructor set up an activity, offered support during its implementation, or even explained the purpose of the activity. This latter piece (explaining the purpose of an activity) was a new idea that emerged exclusively when students discussed constructive types of instruction. Interestingly, many constructive types of instruction use "self-explaining" (Chi & Wylie, 2014, p. 228) as a way to help students work through problems on their own (e.g., "assuming responsibility for learning material on my own"). But, students either did not understand that processing through the problem themselves was the purpose of this type of instruction, or did not understand how this type of instruction helped them to better understand the material. One student shared an example of the former misunderstanding:

> *I guess I never thought about it like that…. I just thought the instructor was trying to be generally vague, or was too busy to answer my questions…. I wish sometimes that they'd share with you why they're doing it. I might not like it, but at least I'll know.* (Participant #15, Male, Data Science Major)

Another student in the same focus group shared an example of not understanding why the instructor posed these ill-structured problems without support:

> *I just don't get [why the instructor would use this type of instruction]. That's not the way I learn, and it's not helpful to me. I just shut down because I get so frustrated…. I have to have somewhere to go to when I get stuck, and [the instructor] wasn't there to help."* (Participant #9, Male, Computer Engineering Major).

Similarly, this was also the result of students being pressed for time and feeling that more constructive types of instruction were a misuse of time:

> *Assuming responsibility for learning material on my own – definitely I would like for all the material to be presented in class and available at all times if necessary and I don't want there to be an expectation that we should learn material on our own. The reason being like if I had all the time in the world, I would not mind that to be an expectation. But most of us are students taking four other courses. I don't have the time for that.* (Participant #4, Male, Biomedical Engineering Major)

Students also shared that confusion about the purpose of participating in a constructive activity stemmed from a lack of understanding why there could be problems with more than one solution in class. One student indicated that he thought being an engineer meant that all of the assumptions to make in solving the problem were clear: *"I don't like solving problems that have more than one answer. Maybe that's just cuz I'm an engineer…. I feel like engineers should* *know understand how to solve these problems immediately."* (Participant #14, Male, Data Science Major). But, when pressed further about always understanding complex problems that could have more than more answer and assuming that there was only one answer, he continued:

> *In my prior experience, when [there are multiple solutions], it's because you can make…an assumption and solve the problem that [one] way or you don't make the assumption and solve the problem the other way…. [He uses an example.] In [my former class], I had been taught "this is the way you solve this problem." But, then I got to [another course in the following semester] and the instructor tells me something completely different. So, the whole time I think I've been doing this wrong…. And I was really frustrated…. It took me until this semester to realize that both ways were technically correct…. I thought, "here's how engineers have solved this," but [it was] "here's one way engineers have solved a part of this."* (Participant #14, Male, Data Science Major)

The student felt frustrated and provided a negative response to this type of instruction, because he thought that he had been taught the wrong way to solve the problem in the past, but the problem was actually a complex one and allowed for multiple ways to address it; however, the student did not discover this until later in the second course. From this quote, it is unclear whether or not the first instructor told him that this was the only way to solve the problem, or if he just assumed that the instructor was giving him the only available solution because he felt that, as an engineer, there should only be one correct answer to the problem.

In some cases, students mistook "assuming responsibility for their own learning" as a lack of instructor support. Students indicated that they did not enjoy this type of instruction because they felt that finding and explaining course concepts was a responsibility of the instructor, or at least that the instructor had some obligation to do this because students were paying to take the course. One student shared her frustration with this type of instruction:

> *I would go and find [out about these concepts], on my own. Sometimes the textbook wasn't the best resource. So, if there was something confusing in the book, I'd go to like Google, and I'd usually end up using something like Khan Academy, or another college's website for that topic…. But, I'm not a big fan of that from the point that I have to spend my time during class learning the material [myself] when I feel like I'm paying to be taught it in class…. [Instead], we were just kind of on our own without the instructor.* (Participant #16, Female, Electrical Engineering Major)

Interestingly, in this example, the student noted that the textbook was not the best resource, and that she did not have a clear direction for where to find the answers to some questions, which may have led to much of her frustration with this type of instruction. In this case, "learning the material" might be directed towards learning how to navigate resources, rather than actually discovering the material for herself. Perhaps, if better equipped or supported with information on which resources were the best alternatives to the textbook, she might have had more direction to assume this responsibility for herself. Instead, she felt "on [her] own without the instructor."

Seeing Utility for Engineering Career

Eight students felt that one of the most rewarding aspects of participating in constructive types of instruction was the confidence that they gained in their ability to become an engineer. These students shared that they saw *more* value in activities which featured constructive types of instruction because they felt that the complexity of these activities meant that they were likely to be successful in the engineering field. One student discussed her thoughts: *"I guess anyone can solve a problem on an assignment or on a test. But, when you're given something complex…and* *then you complete it, you're like 'wow, maybe I can do this after all'…. It's a real confidence booster"* (Participant #10, Female, Electrical Engineering Major). Another student in the same focus group echoed her sentiments:

> *Yeah. I mean, that's the fun of doing the problems and being able to do them. Like if you can solve [a complex problem in engineering] it means you can be a good engineer…. Anyone can sit and watch a lecture. An engineer needs to know how to "do," not "watch."* (Participant #18, Male, Aerospace Engineering Major)

Similarly, other students shared that they enjoyed constructive types of instruction and the initial opportunity to work through the material on their own rather than watching the instructor solve the problem, particularly if it was in a low-stakes environment where they could attempt the problem and then observe how to get the correct answer from the instructor:

> *I liked that I could assume responsibility for learning the material on my own. Because, I could attempt it first. The way I learn, I know, is that I need to attempt the problem on my own first before I ask for help. Otherwise, I'm just listening to someone tell me how to do it and I'm not figuring it out…. I'm not going to have them telling me the right answer when I'm done in two years.* (Participant #13, Male, Computer Engineering Major)

Both students from the previous two quotes saw the value in constructive types of instruction because they knew that there would be a time when they might have to solve a problem on their own in a work setting, and the instructor would not be available to help.

Summary of Response to Constructive Types of Instruction

Similar to the preceding sections on passive and active types of instruction, students generally fell into one of two groups regarding their responses to constructive types of instruction. These groups mostly mirrored the ones discussed in the preceding sections on passive and active types of instruction. The first group consisted of six students (Participants 4, 9, 12, 14, 15, and 20) and consisted of those who felt that the instructor was the primary source of knowledge, and thus should give them the answers to the course concepts discussed during class. For some of the students in this group, they had not moved towards the idea that there could be some complex problems in engineering that might require multiple ways of addressing the issue over constructive types of instruction. Moreover, they had not established themselves as "experts" who could try and find the solutions to these problems on their own. Instead, they still felt that there was a "best answer" to address the issue, and that the instructor had this answer. Other students in this group had moved beyond the understanding of "one perfect solution per problem," but still preferred that the instructor introduce them to these ideas rather than discovering them individually. Often, this was because the sources of material that they believed should help them, aside from the instructor (e.g., textbook, course handouts), were not sufficient enough. Thus, these students struggled to find new sources from which to derive this information, and at least some of these students felt stressed by the extra amount of time needed to find these sources. This latter finding appeared to be more about not necessarily understanding how to navigate constructive types of instruction, rather than a negative perception of this type of instruction.

The second group consisted of four students (Participants 1, 10, 13, and 18). In this group, students felt positively about constructive types of instruction because, like with active types of instruction, this type of learning went beyond simply "knowing" the material. These students felt positively about constructive activities because they could perform the role of the engineer in discovering the problem and identifying potential solutions. These activities allowed students to experiment with doing some of the tasks that had the same complexity they would experience in the engineering field. As with active types of instruction, they realized that this would ultimately make them a better prepared engineer.

Interactive Types of Instruction

Students in all of the focus groups also discussed their responses to interactive types of instruction. These interactive types of instruction included: “solve problems in a group during class,” “do hands-on group activities during class,” “discuss concepts with classmates during class (Discuss),” “work in assigned groups to complete homework or other projects,” “be graded based on the performance of my group,” and “student course content with classmates outside of class.” In fact, this was the most frequently-discussed type of instruction across all five focus groups, and there were four themes that emerged from quotes about interactive instruction: perceiving inconsistent contributions, self-selecting group members, experiencing good instructor implementation of activities, and seeing utility for engineering career.

Perceiving Inconsistent Contributions

Eleven students shared that they believed problems with group work often occurred because of discrepancies or misunderstandings in sharing workload responsibilities and/or the quality of the group work desired, especially when they did not previously know or have experience working with these students (i.e., students were randomly assigned to a group or were asked to purposely select group members that they did not know for the activity). One student shared that it was often hard to get group members to buy into doing the same amount of work in the group:

> *I like being around other people, but I don’t like learning in groups. I find it to be very frustrating because to actually work on something, you’re put in a group to get everyone to collaborate efficiently and effectively and this isn’t always the easiest thing to do….*

> *People have different ideas of what is an equal share of the work. Either that, or they just want to do the bare minimum…. A lot of times when I find myself stuck [in group projects] with a group of peers who don't have that same attitude, I end up putting in a lot more work than they do, only to get the same grade.* (Participant #14, Male, Data Science Major)

Others echoed similar comments, indicating that they did not think positively of working in groups because of lack of consistency in perceptions of the quality of the work that needed to be put into an assignment. For example, students shared personal stories about how their expectations for an assignment did not line up with those of other members in their group. One student shared that she "*always [aimed] for an 'A' on every assignment,*" but that she did not feel others in her previous groups held the same opinion. She added, "*Some want to do the bare minimum so they can just get the project over with. They don't care about the grade as long as it's passing*" (Participant #2, Female, Biomedical Engineering Major). She clarified that "passing" was any grade "C" or better, so her group members' expectations might have simply meant being assigned a grade of "B." Another student shared a similar comment: "*[I don't like group work] because everyone doesn't always have the same idea of ... Or always want to put in the same amount of work into the class*" (Participant #14, Male, Data Science Major). A different student in this same focus group clarified: "*Like [he] said before, they don't put in the same effort, but they get the same grade. If I wrote up 90% [of a final report for the project], why should you get the same grade as me for that?*" (Participant #12, Male, Electrical Engineering Major). In the stories discussed by these students, the misalignment was about the expectations in how much work to put into the assignment, not whether or not to do the assignment at all; however, it is unclear from these conversations whether or not these students asked their group members for help. For example, did these students clarify with group members what their workload expectations were and found that the others' expectations came up short, or did they just expect their group members to take the initiative and do the work until the project was finished? Regardless, these students' feelings about such misalignments were often the source of frustrations with group work.

Similar to the students' aforementioned experiences with inconsistent group members, seven students stated that negative prior experiences with group work were ones where their groupmates did not do *any* work in the group. For example, one student discussed her prior experience in a required math course:

> *For example, my first team in Calculus III ... There was only three of us. And out of the three of us, one person literally did nothing, and the other person wanted to help but didn't know what to do… so they ended up not doing anything either… and then I was basically writing the whole report by myself. And, honestly I felt that it wasn't ... For me it wasn't about the [group work itself], but it was more of the people…. I felt that it was just my bad luck to get such a team*. (Participant #16, Female, Electrical Engineering Major)

Another student shared his experience with a group member who did not complete her portion of the group assignment on time because of conflicts with the U.S. Presidential election:

> *Yeah so I think it was ... I don't know. Something was happening with the election or really something. And it was like on Tuesday, election Tuesday, and we had like a big paper due Thursday. One of the people in our group decided they were gonna work on this like, Tuesday night. And then we were gonna spend all day Wednesday reviewing it. And then she got mad about that because she all caught up in the election or whatever.*

> *So she didn't do anything that night… And then we were scrambling all Thursday morning. And we ended up getting a 60 on it. It was a terrible grade…. It just left a bad taste in my mouth over the whole thing. I felt like we wasted all this time because we did our part and made a 60. So, yeah … I can't really say I feel good about these types of activities because I'm always wondering what could go wrong…and it might be a waste of my time.* (Participant #14, Male, Data Science Major)

Most of all, the student felt that the worst part about this experience was that he felt a bit helpless during the process of working with a group: "*Like your [hands are] tied in a group. No changes can happen. You're stuck with [these group members] for the semester.*" In discussing how he would move forward from this experience, he stated that situations like this automatically invoked a negative perspective: "*I can definitely see how in the future with the same experience, I'd be like, 'Oh boy.' It would feel like I was stuck in another net.... What if I get [another group member] who doesn't do any work?*"

Despite students discussing a lack of consistency from group members across group projects, fifteen students in these focus groups indicated that they would still attempt to participate in group work activities. One student shared that he was willing to give future teammates the "benefit of the doubt" rather than automatically assume they were not going to help with the work:

> *I might not be as motivated but that doesn't mean it's going to actually show up in my work. I might because for example, maybe students didn't help you last time but this time you have a lot of really motivated students. That could actually just entirely change your view. It's not always going to be negative necessarily…. Of course, I'm going to be more cautious and be prepared for the situation where I might have to maybe do all the work*

on my own or something because all my group mates didn't help me or something like that. But I think I would definitely give them the benefit of the doubt until they prove me otherwise, right? (Participant #19, Male, Mechanical Engineering Major)

Another student echoed these comments, but also shared that, rather than leave it up to chance, she would often make it clear what she expected of fellow group members at the beginning of the project to eliminate problems with consistency:

> *So I don't always have the best mindset going in, but based off of previous group projects, like going into the first meeting together, you kind of know you have to set the tone, like, "Okay, here's the deal..." You have to set deadlines, and you want to make sure everyone's on board with that…. If you set the expectations at the beginning, they don't have an excuse for "well, I thought I was only supposed to do this part" or "I didn't know I had to do that." They know what's expected of them.* (Participant #16, Female, Electrical Engineering Major)

In this instance, these students were willing to look past poor prior experiences with group work and either hope for the best-case scenario with new group members or set expectations early in these groups.

I also asked students if they would "penalize" the instructor on an evaluation because of a poor prior experience with a group project. Eighteen students indicated that they would not. The student from the preceding quote shared, "*Personally, I don't think I would relay my displeasure of a group project onto a teacher…. They're just trying to make the classroom interesting… It's not their fault [that the group project went poorly]*" (Participant #11, Male, Electrical Engineering Major). Another student agreed that she would be willing to look past negative prior experiences. But, if after putting in a fair share of work she felt she was getting little assistance from her group members, she suggested that she, too, would not put in her best effort in the future with this same group:

> *Even if I've had a bad experience with group work…, I always try to put forward my best effort [in the beginning], because I want the A…. But sometimes, no matter how you start the project [with certain expectations]…. Some people just don't want to do the work…. And I find it very frustrating from that aspect, but when you're in a group with two other people who just don't really want to do it, it's easy to find yourself just wanting to be done with the project, and not put in your best effort.* (Participant #16, Female, Electrical Engineering Major)

Self-Selecting Group Members

Six students indicated that positive prior experiences with group work made them feel positively about group work in the future, but in each of their examples, these students discussed instances where they were able to self-select their own group members. For example, two students in the focus groups (who were group members together in a previous course) stated that they "felt fine" about group work in their current course because they worked well together:

> *We know what we're getting into when we pair up…. We had a good experience before. I think we made an "A" on the project? [Other student nods.] So, yeah, we didn't have a group project in this course, but if we did, I would feel good about it.* (Participant #5, Female, Chemical Engineering Major)

This discussion brought up several questions about choosing group members for projects. Some students felt that the misalignment in group expectations varied based on the selection process for group members. For example, these students viewed being able to select their own group members more positively because students knew that they could select peers they would "work well with" or peers who had similar goals for the course:

> *Well I definitely notice a difference when you're able to pick your group versus when you're put in a group. When I've been able to pick my group, it's definitely been better, because I pick peers that I know I work well with, and that hope to achieve the same grade as I do.* (Participant #16, Female, Electrical Engineering Major)

Seventeen students agreed that they felt more positively about group work if they were able to select their partners because they generally knew what they could expect out of their group. Furthermore, when asked about how negative prior experiences with group work would impact them in the future, eight of these seventeen students shared that if they were in a course in their major and were able to pick their own groups, they might approach the situation differently, even if they had had a negative experience in the past:

> *I suppose like in a [student's major] class for me, you know more people in your department…. I would be willing to look past other negative experiences because my hope would be that these students are willing to put in the same effort as me…. Plus, if it's in my major, I probably know them. So I'd know who to stay away from.* (Participant #3, Male, Biomedical Engineering Major)

In this example, the student indicated that being able to self-select his groupmates or having a course in his major, where he was familiar with the work habits of his peers, could both be expected to have a positive impact on how this student approached group work in the future.

Experiencing Good Instructor Implementation of Activities

Five students indicated that the preparedness or organization of the instructor, or the way that the instructor provided an introduction or explained the purpose of a type of instruction, was crucial to the success of the activity. In other words, students perceived the amount of support from an instructor as being related to the amount of time and energy the instructor used in setting up the activity. Fifteen students indicated that they felt group projects were the norm in the engineering classroom today, but that these types of activities were not adequately prepared by the instructor. Three students shared that they felt instructors "had to" put group projects on the syllabus because it was a perception of the culture of teaching in engineering (i.e., all instructors should include some kind of group work for students so that they have the experience of working with a team), but that this often translated to them as the instructor being unprepared because it seemed like the instructor included group work without providing any context as to how or why they included this activity. One student shared his rationale: "*Some courses don't really lend themselves to group projects, and are inherently more lecture-style, and I feel like the instructor is just doing a group project because everyone does group projects now. There's no thought behind it"* (Participant #18, Male, Aerospace Engineering Major). This same student went on to discuss the impact that preparation had on how these types of projects were received. In the project he referenced, he felt the instructor did not properly prepare students for the project or offer support during its implementation. He noted this in contrast to an aerospace course where the instructor was well prepared and offered support:

> *Also, how the professor prepares the [project] and direction helps a lot, and how available they are for questions I think is the most important, because the aerospace ones that I liked, the professor was always available. You could find him after like five minutes of searching just to figure out what room he was in, but he'd always answer questions and be able to help you proceed with the project or advise on the next step…. Giving advice beforehand helps, like the instructor in that aerospace course would talk about some previous projects and say what worked decently and what absolutely didn't work,*

so we knew, "Don't do this," before we started. That helped. (Participant #18, Male, Aerospace Engineering Major)

Students also indicated that they felt they were "on their own" for activities, which was helpful if students knew what they were doing in the activity; however, they indicated that they felt the instructor *assumed* that they knew what they were doing, and none of the students wanted to be "*the fool who stood up and said something to the instructor*" (Participant #14, Male, Data Science Major).

Similar to the preceding quotes about rushing through activities or disorganized implementation of certain types of instruction, other students in the focus groups indicated that they felt positively about a course or instructor when different types of instruction were used, but specifically shared that this was only the case if an appropriate amount of time was also reserved for completing the activity. For example, nine students shared that they felt certain activities were often an "afterthought" of the instructor. They stated that their instructors would have the best intentions of having students work on problems in groups during class, but there would not be enough time left by the end of the class period. Instead, instructors would try to "cram" a 15-minute activity into the last five minutes. One student shared, *"He would say 'ok, let's pair up and work this problem' and you're looking up at the clock and thinking, 'eh, I'll sit this one out.' It just doesn't make since because you won't get anything done"* (Participant #20, Male, Mechanical Engineering Major).

Seeing Utility for Engineering Career

Similar to the comments students made regarding passive, active, and constructive types of instruction, students reported that the benefits of interactive types of instruction were often found in the skills that these activities helped them to develop. In fact, three students shared that they enjoyed interactive types of instruction because these activities were teaching them about more than just the material. They saw the benefit in these activities for their future careers in engineering because they understood that they would have to "be a team player" and work with others on engineering projects in the field. In other words, these group activities provided them experience with the professional skills they felt they needed to be a successful engineer. For example, these students indicated that they saw the value in participating in such practices because they were applicable to what they would experience in the field:

> *They're having us do group projects to learn how to better work in a team, just because that's gonna be more of the ... I guess the situation will be, in a few years, once we actually have a job and are working professionally… I think they kind of want us to get used to that, and experience that before we have to do it in the real world…. It definitely prepares you in the aspect that not everyone is going to pull their own weight, and that you have to learn to work with people that always aren't very helpful, or people who are great, and you can learn great things from, because also with group work when you're all collaborating, you do get good ideas from other people.* (Participant #13, Male, Computer Engineering Major)

This student shared that the benefit in participating in interactive types of instruction was found in the applicability of this experience working in groups to an engineering career. In fact, despite many objections during these focus groups to having group members randomly assigned to projects during class (rather than self-selection of group members), students stated that they at least understood why these groups were often randomly assigned. One student shared: "*I mean, you're probably not going to get to pick all your co-workers, right? But, you'll still have to do the work. So, I kind of see it like that in the class*" (Participant #1, Female, Biomedical

Engineering Major). As shared in the section on self-selecting group members, however, just because students understood the purposes of randomly selecting group members did not mean that they always responded positively to it.

Summary of Response to Interactive Types of Instruction

Across each of these themes, students appeared to respond to interactive types of instruction in three different ways, and they could be grouped accordingly. The first group consisted of five students (Participants 2, 8, 11, 12, and 14). These students responded negatively to all interactive instruction. Much like for active and constructive types of instruction, this was the group that felt that the instructor was the ultimate source of knowledge and interactive types of instruction were an unnecessary means by which to learn course concepts and solve engineering problems. Students in this group felt negative about all types of interactive instruction used in their classes.

The second group consisted of four students (Participants 1, 3, 13, and 18). These students were on the opposite end of the spectrum and seemed to understand the benefits of engaging in interactive instruction. Even for this group, however, their response to each individual instance of interactive instruction depended upon how successfully the activity was set up and/or how their group members participated during the project. A poor group experience for these students did not result in a general negative feeling about interactive types of instruction. Rather, these students chalked this up to a poor group experience and were willing to respond positively to interactive experiences in the future.

Finally, the third group of students (five students; Participants 5, 6, 7, 16, and 19) responded somewhere in between these two groups. They acknowledged the benefits of interactive types of instruction, but given the preference, would have rather had a more individualized activity (i.e., active or constructive types of instruction) than work in a group. Much like in the second group, their response to interactive types of instruction was dictated by how successfully the activity was set up and/or the participation of their group members during the project. In this case, however, poor prior group experiences led to increased negative perceptions of interactive types of instruction. If they could not avoid participating in group work in a future course, they worked to influence the situation as much as possible to make the activity a successful one (i.e., self-selected their own group members, set clear expectations for group members at the beginning of the activity).

Chapter Summary

Table 20 provides an overview of the summary sections for each of the four types of instruction discussed in this study. In this table, I summarize both the positive and negative response groups for each of the four types of instruction, with a third "neutral" response added for interactive types of instruction, and I list the participant numbers for students who shared these comments in the focus groups. Note that if the participant is missing from a group in a type of instruction in the table, it is because they did not comment on the type of instruction during the focus groups.

Given the layout of participants indicating positive and negative responses to each type of instruction, it appears students' view regarding passive types of instruction dictated how they would view more active (i.e., active, constructive, and interactive) types of instruction. For example, Participants 4, 7, 8, 11, 12, 14, and 20 all shared positive views of passive types of instruction, and negative ones of either active, constructive, or interactive types of instruction. (Participant 12 shared negative responses to all three of these types of instruction.) Meanwhile, Participants 1, 3, 9, 10, and 19 all shared negative responses to passive types of instruction and

Table 20.
Summaries for Students Qualitative Responses to the Four Types of Instruction

<table>
<tr><th></th><th colspan="2">Positive</th><th colspan="2">Negative</th></tr>
<tr><td>Passive</td><td colspan="2">Passive instruction provides students with knowledge needed as an engineer, and students know what is expected of them.
Participants: 4, 7, 8, 11, 12, 14, 20</td><td colspan="2">Passive instruction relies too much on the instructor and does not prepare students to complete the tasks required of an engineer.
Participants: 1, 3, 9, 10, 19</td></tr>
<tr><td>Active</td><td colspan="2">Active instruction helps students to become a better engineer “in practice.”
Participants: 1, 5, 9, 10, 19</td><td colspan="2">The instructor is the ultimate source of knowledge and is the instructor’s responsibility, and active instruction is not supportive of this.
Participants: 2, 12, 17, 18, 20</td></tr>
<tr><td>Constructive</td><td colspan="2">Constructive instruction helps students to become a better engineering “in practice,” and students understand the complexity of the problems that engineering face which may require multiple solutions.
Participants: 1, 10, 13, 18</td><td colspan="2">Negative: The instructor is the ultimate source of knowledge and the complexity of constructive activities in counterintuitive to the understanding that there is one solution per problem.
Participants: 4, 9, 12, 14, 15, 20</td></tr>
<tr><td>Interactive</td><td>The instructor is not the only source of knowledge and interactive instruction provides student with the types of professional skills needed as an engineer.
Participants: 1, 3, 13, 18</td><td colspan="2">Students do not feel completely negative about interactive instruction; however, given the choice, they would rather do an individualized (active or constructive) activity instead of one featuring group work.
Participants: 5, 6, 7, 16, 19</td><td>The instructor is the ultimate source of knowledge, and group work is an unnecessary way to learn course concepts and how to solve problems.
Participants: 2, 8, 11, 12, 14</td></tr>
</table>

positive ones to either active, constructive, or interactive types of instruction. This appears to delineate a sticking point for students where, depending on their views of passive types of instruction (particularly lecture), students are either receptive or opposed to more active ones.

Looking broadly across all of the themes introduced in this chapter, there were some ways that student response to each type of instruction aligned across the four types. For example, “seeing utility for engineering career” emerged as a theme in all four types of instruction, and in each, students discussed how these types of instruction prepared them for both short-term (e.g., exams) and long-term (e.g., engineering career) goals. For passive, this utility was in the form of the application of knowledge needed to be successful in this course or in their engineering career, while for active and constructive types of instruction, this was more about strengthening their confidence that they could perform the tasks required of an engineer. Similarly, interactive types of instruction provided them with the professional skills they needed for their future careers (e.g., experience working in groups on projects).

Another of these, “experiencing good instructor implementation of activities,” emerged in three of the four types of instruction (active, constructive, and interactive). In each of these themes, students shared that the way that instructors introduced or the support offered during the activity often determined the success or failure of the activity (in their eyes). For active and constructive types of instruction, this was often as a result of student’s reliance upon the instructor as the sole source of knowledge in the course, as they struggled to move to a point of understanding their own role in discovering knowledge or problem solving. For constructive types of instruction, this differed slightly in that students sometimes did not understand to purpose of these activities, particularly those problems that were ill-structured or involved multiple answers. For interactive types of instruction, students related this theme to the amount of time that the instructor used in setting up activities involving group work. If student felt that the group work was poorly structured or if little support was available during roadblocks in groups, they indicated a negative response.

The remaining themes in this chapter only emerged for one type of instruction and were noted as characteristics for each type of instruction. For example, across passive types of instruction, “understanding expectations of lecture” and “being prepared for the exam” were explicitly discussed in term of lecture because students believe that this was the purpose of passive types of instruction (i.e., the instructor disseminating knowledge to students). “Experiencing novelty of the material” emerged for active types of instruction because some students indicated that they only felt comfortable doing these activities if they were familiar with the material. Otherwise, they expected the instructor to provide them with information on the material first before they participated in these activities. For interactive types of instruction, the remaining two themes “perceiving inconsistent contributions” and “self-selecting group members” were tied to how group members did (or did not) meet expectations of the student and how comfortable they were with their peers, especially if they were able to self-select them. These are often outside of the instructor’s purview of things he or she can control with interactive types of instruction, but it appears that providing support or giving instruction on how to make group activities successful (i.e., instructor strategies) was helpful to students in knowing that the instructor was trying to make the activity work as smoothly as possible.

Chapter 6: Discussion

In exploring the relationship between student response and types of instruction in the engineering classroom, the purpose of this study was multifaceted. First, I wanted to discover what types of instruction students perceived as being implemented in the five engineering classrooms at this institution. Second, I wanted to explore how students responded to EBIP in those classrooms. Finally, I wanted to better understand the relationship between students' response to EBIP in their prior and current courses, as well as the frequency with which each type of instruction was perceived to be used and how students would subsequently evaluate their course and instructor in their current courses.

In this chapter, I present a discussion of the results synthesized from both my quantitative and qualitative analyses in the previous two chapters. This discussion is organized into four sections. First, I discuss the process by which I analyzed the results from the quantitative and qualitative chapters for this discussion, utilizing a concurrent nested model for mixed methods analysis (Creswell et al., 2003). Second, I provide a general review of the results that address the broader research questions:

1. What types of instruction are being used in introductory engineering courses at a large research university?
2. How do students respond to different kinds of instruction in these courses? How does their previous experience with different kinds of instruction influence their response to its use in their current course?

3. What relationships exist between prior response, current response, the frequency with which each type of instruction is used in the current course, and how students subsequently evaluate the course and instructor?

Following the discussion of these research questions, I summarize the implications for research given the findings from this study. Finally, I describe recommendations for future research in this subject area and offer some concluding thoughts.

Process of Analyzing Results from Quantitative and Qualitative Chapters

As discussed briefly at the beginning of Chapter 3, I utilized a mixed-methods design in this research study to gather both quantitative and qualitative data to answer my broader research questions. Given that survey instruments (quantitative) and focus groups (qualitative) were employed during a similar time frame but focused on different aspects of the research questions, I chose to analyze these results using a concurrent nested model for mixed methods analysis (Creswell et al., 2003). Thus, after data collection, I analyzed the quantitative results and reported these findings in Chapter 4 to broadly understand how students responded to each of the types of instruction they encountered in their classrooms. Then, I used the qualitative results in Chapter 5 to uncover why students responded in the various positive and negative ways to each type of instruction. In this chapter, I consider the broader implications for student response found in the quantitative results, while providing context for these results based on qualitative findings. Thus, in the discussion sections that follow, I synthesize how the specific research questions in Chapters 4 and 5 fit into my broader questions in Chapter 1. There are exceptions, particularly with regards to Research Questions 1 and 3. For Research Question 1, given that this is a study about how *students* respond to different types of instruction in the engineering classroom, questions regarding why some types of instruction are used instead of others is best reserved for *instructors* of these courses, which is beyond the scope of this study. Thus, only the quantitative findings are discussed for this research question. For Research Question 3, despite having a section in my focus group protocol to discuss how students' prior experiences might impact future responses each type of instruction, not enough data emerged from these focus groups to develop an adequate response to this research question. Much of this had to do with students' frame of reference for their quotes. For example, students would share their experiences with a type of instruction, but not whether it was in context to a previous course or another course they were taking currently. Since this could not be specifically attributed to the relationship between prior and current response, I only use the quantitative findings for this research question.

Certainly, the process of synthesizing results from the quantitative and qualitative sections of this study was more iterative than might be assumed from the linear way in which this dissertation has been written. In other words, there was no possible way to analyze the quantitative results from my surveys, resolve my predispositions as to what was found in these results, and start anew on the qualitative results, and vice-versa. Instead, I would find questions that emerged after consulting each section and attempt to determine how the respective sections helped to address these questions and what remained to be discovered after analyzing the results of this study. Thus, the next section represents the findings that emerged from this iterative process.

Review of Results to Research Questions

Research Question 1: What types of instruction are being used in introductory engineering courses at a large research university?

As a refresher, in Survey 1, I included 21 of the most commonly-used "types of instruction" items in engineering classrooms from prior research (Table 3; DeMonbrun et al., 2017), which were then aligned with Chi and Wylie's (2014) ICAP model. Then, I asked students to report how often they had done each type of instruction so far in the course (this survey was implemented between weeks 5 and 7 of a 16-week semesters). An illustration of the reported use by each type of instruction is provided in Figure 10.

Regarding my first research question, I found several interesting results based on my quantitative results. First, considered broadly, the ICAP classification for the 21 types of instruction in this research study showed variation in the types of four overarching categories of instruction encountered in the five engineering courses studied. Overall, students reported that passive types of instruction were the most commonly-used (passive mean = 3.94), but this was primarily weighted by students' reports of *often* "listening to the instructor lecture" (mean = 4.28). In contrast, the least frequently reported activity in this classification, "getting most of the information need to solve homework directly from the instructor," was only reportedly used *seldom* (mean = 2.08). Students also indicated experiencing other kinds of instruction frequently. For example, students reported that they *sometimes* experienced constructive types of instruction (mean = 3.45). But again, the consistency within each type of instruction was often mixed. For example, students indicated that they were asked to "find additional information not provided by the instructor to complete assignment" *often* in their courses (mean = 4.08), while "solving problems that have more than one correct answer" was reportedly used *seldom* (mean = 1.91).

Students indicated that active and interactive types of instruction were used less often. Overall, they shared that these types of instruction were being used between *seldom* and *sometimes* in their courses (active mean = 2.28; interactive mean = 2.59). For active types of instruction, this ranged from "previewing concepts before class" (mean = 3.76) to "ask the instructor questions during class" (mean = 2.48). For interactive types of instruction, this ranged

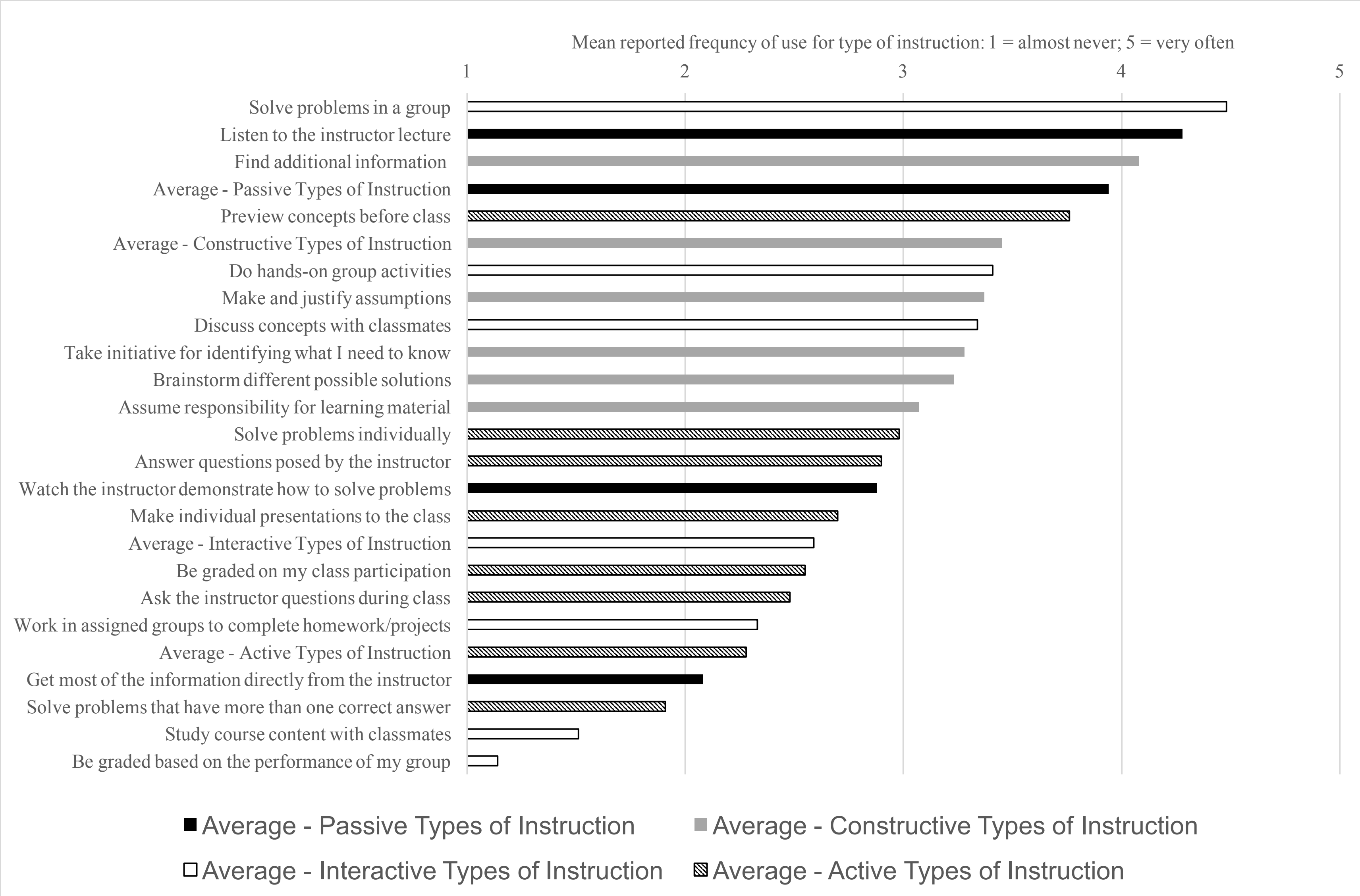

Figure 9. Mean of reported use of each type of instruction ordered from most frequent (very often) to least frequent (almost never).

from “solving problems in a group during class” (mean = 4.48) to “being graded based on the performance of my group” (mean = 1.14).

These reported differences across all types of instruction, however, are also course specific. As indicated in the ANOVA tests of differences, three of the four types of instruction (passive, active, and interactive) were found to have statistically different patterns of perceived usage in the five courses studied ($p<0.001$). Treating these types of instruction in terms of four broad classifications ignores the variation within the individual types of instruction, however. In fact, there were statistically significant differences in reported use of two of the three passive, four of the six active, three of the six constructive, and four of the six interactive types of instruction (13 out of 21 total; $p<0.001$). While these results do not point to the prevalence of the use of one type of instruction over another, they do suggest that instructors have the flexibility to incorporate many different types of instruction in their classroom, and that students will often be exposed to several different types of instruction during their progression through engineering coursework.

Research Question 2: How do students respond to different kinds of instruction in these courses? How does their previous experience with different kinds of instruction influence their response to its use in their current course?

Regarding my second research question, the analysis from my research study sheds light on how students responded to these types of instruction in both their prior courses and the current course in which they were enrolled. For questions on their prior courses, in Survey 1 students were asked to identify a course they took in the previous semester (Fall 2016) that was most relevant to their currently enrolled course and then were asked to indicate their typical response[3]

[3] Response scale: 1 = Almost never (<10% of the time); 2 = Seldom (~30% of the time); 3 = Sometimes (~50% of the time); 4 = Often (~70% of the time); 5 = Very often (>90% of the time)

to four commonly-used types of instruction, identified in previous research studies (DeMonbrun et al., 2017). These types of instruction were:

- “Listen” (passive),
- “Answer Q’s” (active),
- “Brainstorm” (constructive), and
- “Discuss” (interactive).

Then, in Survey 2, students were asked to indicate their typical response to the same four types of instruction in their currently enrolled course.

Before analyzing the differences across prior and current courses, I found it important to first investigate whether or not student response to instructional types varied by the course in which they were currently enrolled. After calculating ANOVA, MANOVA, ICC and DEFF statistics for both prior and current responses, I found no significant group variation between the courses in my research study. This finding is important for two reasons. First, by eliminating the possibility of intergroup variation in students’ responses, I was able to analyze this data at the individual level, rather than having to apply group-level clustering to my analyses using the student response data. Second, the finding itself that there is no group variation across these courses is an important one, as it would have suggested that there were other group-level characteristics (e.g., characteristics of the instructor or discipline) that correspond to how students respond to an activity.

The results from my **quantitative** analysis of student response to the four types of instruction encountered in prior and current courses suggest that different types of instruction can elicit different responses. For example, in prior courses, students reported *often* finding value in “Listen” (mean = 3.78), while only *sometimes* feeling positive about the activity and instructor (mean = 2.83) and *sometimes* participating in the activity (mean = 3.20). Similar responses were also observed in the current course (value mean = 3.25; positivity mean = 3.02; participation mean = 3.05). Means across three of the four types of instruction (i.e., all except "Discuss") for the prior course were similar, *often* finding value (passive = 3.78; active = 3.73; constructive = 3.82), *sometimes* feeling positive about (passive = 2.83; active = 2.66; constructive = 2.78), and *sometimes* participating in (passive = 3.20; active = 3.08; constructive = 3.10) these three types of instruction. These similarities were also found in the current course, but students only indicated *sometimes* finding value (passive = 3.25; active = 3.16; constructive = 3.13) in these activities, and *sometimes* feeling positive about (passive = 3.02; active = 3.20; constructive = 3.02) and *sometimes* participating in (passive = 3.05; active = 3.23; constructive = 3.24) these types of instruction.

For the interactive type of instruction ("Discuss"), significant differences were observed, but only for one type of response in both students' prior and current courses: the value students placed on the type of instruction. For the prior course, students indicated that they perceived less value, sharing that they *seldom* did so with this type of instruction (mean = 2.01). Surprisingly, these findings were not mirrored for the positivity and participation response constructs, where students shared *sometimes* feeling positive about (mean = 2.73) and *sometimes* participating in (mean = 3.23) this type of instruction. In other words, while students might not value this type of instruction, they still thought positively about the activity/instructor and participated in the activity regardless of their feelings. Additionally, although the mean values were different for students' response to "Discuss" in their *current* course, the message remained the same. The only response construct with significant variation was value, and similar to the prior course findings, students *seldom* found value in this type of instruction (mean = 2.17). And, again, despite indicating a lower value for this type of instruction, this did not appear to impact the positivity they felt towards the activity/instructor (mean = 3.17) or their participation in the activity (mean = 3.20).

The findings from the **qualitative** analysis shed light on possible ***reasons*** why students might value “Discuss” less, but still maintain positivity and participate in the activity. Participant #16 (Female, Electrical Engineering Major) shared that she found it frustrating to be in groups sometimes because “*some people just don’t want to do the work…. And I find it very frustrating from that aspect, but when you’re in a group with two other people who just don’t really want to do it.*” The indication of frustration could reflect a negative response to a question like, “I felt the effort it took to do the activity was worthwhile.” Participant #14 (Male, Data Science Major) shared a similar response, indicating that he was apprehensive about interactive types of instruction: “*I can’t really say I feel good about these types of activities because I’m always wondering what could go wrong…and it might be a waste of my time.”*

Despite these apprehensions, students were still willing to think positively about and participate in “Discuss.” This was reflected in the quantitative results and supported by qualitative findings. Results from Table 14 in the quantitative chapter showed that positivity for “Discuss” significantly increased from students’ responses in the prior course to the current course ($p<0.001$). As evidenced in the qualitative results, students said that they would not “penalize” instructors who utilize these types of instruction. For example, Participant #11 (Male, Electrical Engineering Major) indicated that his negative feelings about group work would not translate to negative feeling about an instructor: *“I don’t think I would relay my displeasure of a group project onto a teacher…. They’re just trying to make the classroom interesting… It’s not their fault [that the group project went poorly].”* From a participation standpoint, students are also still willing to contribute to these activities. For some, they realize that participating in groups is an inevitable part of the engineering field, and they are likely going to have to deal with groupmates who do not contribute as much to the assignment. Participant #1 (Female, Biomedical Engineering Major) shared, "*I mean, you're probably not going to get to pick all your co-workers, right? But, you'll still have to do the work. So, I kind of see it like that in the class.*" Furthermore, many students were still willing to give their best effort despite negative experiences in the past, as reflected by Participant #19 (Male, Mechanical Engineering Major): "*I might not be as motivated but that doesn't mean it's going to actually show up in my work.*"

The earlier quotes suggest that although students think positively about or are willing to participate in a certain type of instruction, they do not necessarily feel that their time and/or effort is being effectively used by such practices, as reflected through the value construct. This comment was shared by Participant #14 (Male, Data Science Major), who specifically said, "*it might be a waste of my time.*" Additionally, centering the value of a type of instruction on how it might impact their grade was a common theme. Participant #12 (Male, Electrical Engineering Major) commented, "*they don't put in the same effort, but they get the same grade. If I wrote up 90% [of a final report for the project], why should you get the same grade as me for that?*" Participant #2 (Female, Biomedical Engineering Major), who shared in the focus group that she "*always [aimed] for an 'A' on every assignment,*" gave a similar response: "*Some want to do the bare minimum so they can just get the project over with. They don't care about the grade as long as it's passing.*"

Regardless, while perhaps not evident from their participation in the course, students might not see the benefits of interactive types of instruction in the engineering classroom (e.g., encouraging teamwork and collaboration in engineering graduates, or working with difficult peers on important tasks), which could become a barrier to the use of these types of activities if they are not set up or executed properly. For example, Fredricks et al. (2004) noted that, although students can often complete routine assignments (e.g., memorization) by simply paying attention and staying on task, in order to achieve deeper levels of understanding, they need to become fully engaged in the material through deeper learning strategies, such as complex problem-solving, working through material on their own, or solving ill-structured problems in groups. If students are only participating in "Discuss" without fully engaging in the process, or if their form of participation (i.e., how they might indicate they participate in this type of instruction on these surveys) is short of the type of cognitive complexity signaled in Chi and Wylie's (2014) conceptualization of interactive types of instruction, they might struggle to achieve these deeper levels of understanding while working in groups. For example, Chi and Wylie (2014) note that for interactive types of instruction, students must be involved in the process of the constructing behavior with others in the group. Perhaps, these students' "participation" only has to do with being present in the group, rather than fully participating in the process.

Research Question 3: What relationships exist between prior response, current response, the frequency with which each type of instruction is used in the current course, and how students subsequently evaluate the course and instructor?

Regarding my third research question, the quantitative results from my research study helped to uncover what relationships exist between prior and current response to each type of instruction, the frequency with which each type of instruction was used, and how students subsequently evaluated their course and instructor. Students were asked about the following types of instruction:

- "Listen" (passive),

- "Answer Q's" (active),
- "Brainstorm" (constructive), and
- "Discuss" (interactive).

Turning directly to the final-stage of the hierarchical multiple regression model, which included controls for student demographics (gender, race/ethnicity, citizenship, class standing), grade data (student's GPA and expected grade in the course), student response to all four types of instruction in the prior and current courses, and the perceived frequency of use for each of these four types of instruction, I found that, *for prior response*, only the passive type of instruction had a significant relationship with students' evaluation of the course and instructor. In this instance, students' value regarding ($\beta = 0.201$; $p<0.001$) and participation in ($\beta = 0.257$; $p<0.001$) "Listen" had a positive relationship with students' evaluation of the course and instructor. In contrast, only the non-passive types of instruction (active, constructive, and interactive) showed significant relationships between student response to these types of instruction *in the current course* and students' evaluation of the course and instructor. For "Answer Q's" (active) and "Brainstorm" (constructive), I found significant positive relationships between the value of (active: $\beta = 0.198$; $p<0.001$; constructive: $\beta = 0.260$; $p<0.001$) and participation in (active: $\beta = 0.193$; $p<0.001$; constructive: $\beta = 0.135$; $p<0.001$) these types of instruction and students' reported evaluation of the course and instructor. For "Discuss" (interactive), significant positive relationships were found between value of ($\beta = 0.102$; $p<0.01$) and positivity regarding ($\beta = 0.149$; $p<0.001$) this type of instruction and students' evaluation of the course and instructor. Finally, I found that the frequency with which all four of these types of instruction were used had a significant positive relationship with students' evaluation of the course and instructor (passive: $\beta = 0.115$; active: $\beta = 0.195$; constructive: $\beta = 0.187$; interactive: $\beta = 0.095$; all $p<0.001$).

Taken altogether, it appears these findings are context-specific, depending on the type of instruction being used in the classroom. For example, students' prior feelings about "Listen" appear to have a relationship with course evaluation, but feelings about this in the current course do not. This finding suggests that, no matter how effectively the instructor implements this in their current course, students' responses to this type of instruction from prior experiences can dictate how they will ultimately evaluate the course and instructor.

This could be reflected in the "understanding expectations of lecture" theme in the qualitative results. For example, all twenty students in these focus groups shared that their experiences with passive types of instruction were similar from course-to-course and that this consistency was often a benefit of passive instruction. So, if students' expectations of passive types of instruction do not change from course-to-course, it is plausible to suggest that students will know what to expect of passive instruction from their prior courses, and little would change regarding these expectations. This expectation can lead to both positive and negative responses to passive types of instruction.

The counter is true for active, constructive, and interactive types of instruction. Students' prior responses to these more active types of instruction do not have a significant relationship with course evaluation, while their value, positivity, and/or participation (depending on the type of instruction) in the current course can be associated with changes in course evaluations. Finally, higher frequency of use is also associated with higher evaluation scores, suggesting that repeated exposure to the type of instruction can have positive benefits

Implications for Research

As a result of the findings that have emerged from this research study and my effort to better understand student response to the different types of instruction used in the classroom, several implications should be noted from these results.

Implication #1: Institutional context should be considered when examining the use of EBIP in the engineering classroom.

As discussed in Chapter 1, there are many concerns that the use of evidence-based instructional practices (EBIP) in the engineering classroom has been limited (Friedrich et al., 2007; Handelsman et al., 2004; Hora et al., 2012; PCAST, 2012; Singer et al., 2012). In fact, when examining a large sample of engineering faculty, Cutler et al. (2012) found that only 52% of faculty were actively using EBIP in their classrooms. The results of this research study suggest that these practices are more widespread in these five courses than what could be anticipated from prior research.

In each of the five randomly sampled courses in this research study, students indicated that faculty are using multiple techniques at least some of the time in their classrooms. Although this does not imply that all faculty are implementing multiple types of EBIP in their classrooms, it does suggest that some faculty do use EBIP and some do use several different techniques to challenge their students beyond the typical lecture-oriented approach. Future research should examine the extent to which these findings are true, and should explore how institutional context plays a role in the use of these practices in engineering courses. Are these results specific to the University of Michigan and institutions like it, or perhaps as calls for the use of EBIP in the engineering classroom have increased (Jamieson & Lohmann, 2009, 2012; Malcom & Feder, 2016; PCAST, 2012), have faculty become more receptive to implementing these practices in their classrooms? In support of this claim, even additional research using this survey outside of this study across 18 different engineering classrooms in the United States suggests that a variety of teaching methods are being often used (Nguyen et al., 2017b).

As noted in Chapter 3, there is some concern as to whether students' reports of the types of instruction they perceive to have encountered in their classrooms are representative of what actually occurred in the classroom, and researchers focusing on this area should continue to utilize different means of triangulation, particularly through observations, focus groups, and interviews, to determine the extent to which these reports from students are accurate. For example, during initial phases in the development of the StRIP instrument, we found that the multiple perspectives gained from the use of triangulation through classroom observations, student focus groups, faculty interviews, and faculty survey collection strongly supported some elements of our the StRIP survey (e.g., how students participated in activities), while offering additional data for other elements of the survey (e.g., the different ways in which students negatively respond to these activities; Shekhar, Prince, Finelli, DeMonbrun, & Waters, 2018).

Implication #2: Researchers need to discover more about how faculty can engage students in positive responses to EBIP, including encouraging the use of instructor strategies for implementing in-class activities.

Prior research has indicated that student resistance to EBIP, through either student evaluations of teaching or by other means inside of the classroom, is an obstacle to faculty choosing to implement these practices in the classroom (Borrego, Froyd, & Hall, 2010; Dancy & Henderson, 2012; Finelli et al., 2014; Fraser et al., 2014; Froyd et al., 2013; Henderson & Dancy, 2007; Seidel & Tanner, 2013). But, the findings in this study suggest that student participation in EBIP might be more widespread than anticipated at institutions like the University of Michigan.

Based on the results across the four types of instruction measured in this study, it would appear that students in these classrooms are at least *sometimes* likely to participate in all types of instructional practices. Again, this is consistent with the prior research using this survey instrument to study student response to instructional practices in 18 different engineering classrooms across the United States (Nguyen et al., 2017b).

This is not to say that a lack of participation is entirely absent from the classroom. Indeed, even the results in the focus groups suggest that students might be less likely to participate in the activity if they do not see the value in or feel positively about the type of instruction. This is particularly true for the interactive type of instruction examined in this study ("Discuss") as, in the qualitative findings, Participant #14 (Male, Data Science Major) noted: *"I can't really say I feel good about these types of activities because I'm always wondering what could go wrong…and it might be a waste of my time."* These responses can be bimodal in nature, often segmenting groups of students into positive and negative categories, as illustrated in Table 20 of Chapter 5. Some students in the focus groups said that they prefer more passive types of instruction, and thus show more positive response to their use in the classroom, while others in the focus groups saw a greater benefit in using more active types of instruction and responded positively to their use.

There are several key takeaways based on the findings from this research study. First, instructors should be explicit about why they have chosen to use active, constructive, and interactive types of instruction in their classrooms. This is particularly true for group work or projects where students might be randomly assigned to groups with unfamiliar students. For example, students shared that they often felt that group projects were put into place because, as shared by Participant #18 (Male, Aerospace Major) in the focus groups, "*everyone does group* *projects now*" and "*there's no thought behind it*." On the other hand, students like Participant #13 (Male, Computer Engineering Major) shared that they did see the purpose of group work: *They're having us do group projects to learn how to better work in a team, just because … I think they kind of want us to get used to that, and experience that before we have to do it in the real world."* It is unclear if instructors are using group work for the wrong types of assignments, or if students just believe this to be the case because the instructor has not made it explicitly clear *why* they have chosen to use an interactive type of instruction here. In prior research using this survey instrument, Finelli et al. (2018) and Nguyen et al. (2017a) found that using strategies to reduce resistance to EBIP were effective in generating greater participation and less distraction in these activities, while also improving the overall evaluation of the instructor and the course. Such approaches include explanation (e.g., instructors explain the purpose of the activity to the class) and facilitation (e.g., instructors promote engagement and keep the activity moving) strategies.

Second, as indicated in the focus groups, the lack of value in group activities might be linked to how students are being graded in the course. Students often discussed not seeing value in these group activities because course grading focused around quizzes and examinations. In other words, students might find greater value in lecture-oriented types of instruction because they are ultimately graded on how well they perform on quizzes and examinations, and instructors often provide material useful for these grading structures through lecture.

Implication #3: Instructors may be able to worry less about students not participating in these practices based upon prior experiences, and instead can focus on the type of instruction that they want to use in the current course.

The results of the hierarchical multiple regression suggest that students' prior responses to instruction impact how they subsequently respond to the same type of instruction in another course *only* for "Listen." In this instance, the prior response that students had to lecture, but not their current response, was significantly associated with their overall evaluation of the course and instructor. This was also reflected in qualitative data. For example, Participant #19 (Male, Mechanical Engineering Major) shared his dismay when learning that his new instructor would rely solely on lecture: "*I did have that feeling again, "Oh my gosh. It's one of those professors." … [Lecture] just doesn't grab my attention."* For active, constructive, and interactive types of instruction, it appears that students' prior responses were not linked to their evaluation of the course and instructor, but rather that there was an association between response to these types of instruction in the current course and course/instructor evaluations. This, too, was reflected in the qualitative results. For example, Participant #1 (Female, Biomedical Engineering Major) shared how she thought she and her classmates benefitted from "real world" problems using active types of instruction:

> *Everyone in the class hears, oh, wow, [this problem] is a real-world example. That's a really cool application... That could be me [as an engineer]. That could be something I'm working on in the future. I feel like that was a very, very, very valuable aspect of the class.*

Similarly, Participant #13 (Male, Computer Engineering Major) shared that he understood why his instructors used interactive types of instruction in the classroom, as a way to build professional skills for working with different team members:

> *They're having us do group projects to learn how to better work in a team…. It definitely prepares you in the aspect that not everyone is going to pull their own weight, and that*

you have to learn to work with people that always aren't very helpful, or people who are great, and you can learn great things from.

In both instances, students shared positive critiques of the course and instructor based on their use of non-passive types of instruction.

These findings regarding student participation in EBIP mirror prior research which also uses the StRIP instrument. For example, in a study spanning 179 students at three different institutions, Nyguyen et al. (2017a) found no evidence of any relationship between the adoption of active learning strategies and students responding negatively on evaluations of the course and instructor. In an expanded study using the StRIP instrument of introductory engineering courses at 18 different institutions (n=1,051), Finelli et al. (2018) indicated little resistance to active learning, sharing that students *sometimes/often* participated in these activities, and *often* valued and felt positively about them. Furthermore, they found a significant relationships between the use of strategies where the instructor explained or facilitated the activity and positive evaluations of the course and instructor (as highlighted in Implication #2).

Directions for Future Research

Questions still remain regarding the impact of prior experiences on future response to these types of instruction. First, as noted in the limitations, this study only examined student response to four ICAP instructional approaches identified by Chi and Wylie (2014). Future research should address other types of instruction to investigate whether findings regarding student response to these practices hold similar to those discussed in this research study. Furthermore, this research study only examined courses at one large, research-intensive institution. Future studies should continue to study instruction across different types of institutions to see if these findings are replicated. For example, would engineering programs that serve more non-traditional populations of students (master's colleges and universities and community colleges) feature similar results? Or, would a small, liberal arts college have instructors with additional emphasis on EBIP when compared to this institution? These types of studies will help researchers to better understand whether or not these types of results are generalizable to all populations, rather than just the population in the sample of this study.

Second, although this study examined if students had experienced each type of instruction in a previous course, it did not determine *how often* or *in how many other courses* students had experienced it. For example, perhaps each of these types of instruction had been so often utilized in prior course experiences that it had become routine for these students. Additionally, it is likely that many students had several experiences with active learning in high school. Future studies should investigate how the difficulty of the content or process of the activity might impact how students respond to it, and how the frequency of the use of each type of instruction in a prior course might impact student response in a future course. Additionally, future studies should aim to connect multiple data points, such as self-report surveys, observations of the classroom, and faculty and student interviews to further explore these relationships.

Third, there are many ways that the surveys used in this research study could be improved. I found that, contrary to prior iterations of this survey, only one participation construct emerged, while that construct comprised two separate items (participation and distraction constructs) in previous applications of the StRIP instrument. Additional administrations of the instrument and factor analyses will help to improve these measures for future research studies. Furthermore, student reported data about the types of instruction used in the course should be supplemented with both instructor reports of the same types of instruction and classroom observations. The former will help to identify whether some of these types of instruction were those which students did on their own (i.e., not solicited by the instructor), and the latter will help to verify if these frequencies are accurate representations of what actually occurs in the classroom. In future studies, researchers should include both instructor and classroom data to help triangulate what occurs in the classroom and verify the reliability of these reports.

Conclusion

Although EBIP have long been recognized as being beneficial for student learning (Johnson et al., 1991), the nature with which student respond to such practices has not been as thoroughly investigated. In other words, these types of practices are beneficial to students, but do students share similar feelings about their benefits, and do students feel that these practices adequately prepare them for an engineering career? Given that student participation is clearly an integral part of the success of these EBIP, it is important to understand how students are responding to the use of these practices, particularly in the field of engineering. The current study aimed to fill these gaps in the literature by investigating how students respond to various uses of different types of instruction in the engineering classroom. Furthermore, little is known about what relationships exist between prior response, current response, the frequency with which each type of instruction is used, and how students subsequently evaluate the course and instructor, and this study was designed to better understand these relationships.

In this research study, I discovered that the perceived use of EBIP practices in these five courses at the University of Michigan shows promise of more active types of instruction being used in these engineering classrooms. Additionally, I discovered that students in this sample often have positive responses to more constructive and active types of instruction. In contrast, I found that students often placed a lower value on the interactive type of instruction examined in this study, and based on focus groups, found that this was often caused by poor prior experiences with group work in past courses. Furthermore, through a hierarchical multiple regression model, I found positive relationships between student evaluations and their prior response to the passive type of instruction and current response to active, constructive, and interactive types of instruction. I also found that the frequency with which each type of instruction is used is associated with similar increases/decreases in students' evaluation of the course and instructor.

These results are certainly context-specific, as the University of Michigan College of Engineering stresses the importance of these types of instruction, and it provides considerable support for their inclusion in the engineering classroom. Thus, these results may not be typical; however, this study represents another step in better understanding student response to types of instruction in the engineering classroom at the University of Michigan, and I hope this study can be used to better inform future research in this area. I look forward to continuing to develop a better understanding of the phenomena presented in this study, and investigating the questions from my directions for future research section.

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Appendix A. Factor Loadings for StRIP Survey Instrument (DeMonbrun et al., 2017)

Table A.1
Confirmatory Factor Analysis Estimates for Ideal Types of Instruction in StRIP Instrument (DeMonbrun et al., 2017)

Instrument item	Standardized factor loadings	Standard error	Item reliability (R^2)	Construct reliability	Average variance extracted
Factor 1: Passive				0.65	0.80
Listen to the instructor lecture during class.	0.62	0.09	0.51		
Watch the instructor demonstrate how to solve problems.	0.60	0.08	0.52		
Get most of the information needed to solve the homework directly from the instructor.	0.51	0.08	0.63		
Factor 2: Active				0.73	0.85
Make individual presentations to the class.	0.43	0.08	0.72		
Be graded on my class participation.	0.42	0.08	0.73		
Solve problems individually during class.	0.55	0.06	0.71		
Answer questions posed by the instructor during class.	0.74	0.04	0.67		
Ask the instructor questions during class.	0.74	0.04	0.67		
Factor 3: Constructive				0.77	0.86
Make and justify assumptions when not enough information is provided.	0.51	0.07	0.76		
Find additional information not provided by the instructor to complete assignments.	0.66	0.05	0.72		
Take initiative for identifying what I need to know.	0.60	0.06	0.73		
Brainstorm different possible solutions to a given problem.	0.50	0.07	0.75		
Assume responsibility for learning material on my own.	0.76	0.05	0.69		
Factor 4: Interactive				0.80	0.88
Solve problems in a group during class.	0.72	0.05	0.74		
Do hands-on group activities during class.	0.63	0.06	0.76		
Discuss concepts with classmates during class.	0.64	0.06	0.77		
Work in assigned groups to complete homework or other projects.	0.70	0.05	0.75		
Be graded based on the performance of my group.	0.44	0.07	0.80		

Study course content with classmates outside of class.	0.61	0.06	0.77

Table A.2

Confirmatory Factor Analysis Estimates for Student Responses to Instruction in StRIP Instrument (DeMonbrun et al., 2017)

Instrument item	Standardized factor loadings	Standard error	Item reliability (R^2)	Construct reliability	Average variance extracted
Factor 1: Value				0.87	0.95
I felt the time used for the activity was beneficial.	0.71	0.04	0.89		
I saw the value in the activity.	0.84	0.03	0.80		
I felt the effort it took to do the activity was worthwhile.	0.89	0.03	0.74		
Factor 2: Positivity				0.72	0.86
I felt positively towards the instructor.	0.66	0.07	0.64		
I felt the instructor had my best interests in mind.	0.73	0.07	0.53		
I enjoyed the activity.	0.57	0.07	0.72		
Factor 3: Participation[a]				0.77	0.84
I participated actively (or attempted to).	0.58	0.08	0.70		
I tried my hardest to do a good job.	0.67	0.08	0.72		
I pretended but did not actually participate.	0.71	0.07	0.74		
I rushed through the activity, giving minimal effort.	0.64	0.09	0.68		
Factor 4: Distraction[a]				0.73	0.85
I distracted my peers during the activity.	0.58	0.08	0.75		
I talked with classmates about other topics besides the activity.	0.39	0.05	0.68		
I surfed the internet, checked social media, or did something else instead of doing the activity.	0.65	0.06	0.65		
I pretended but did not actually participate.	0.70	0.06	0.67		
I rushed through the activity, giving minimal effort.	0.63	0.06	0.65		
Factor 5: Evaluation				0.72	0.93
Overall, this was an excellent course.	0.82	0.05	0.60		
Overall, the instructor was an excellent teacher.	0.82	0.05	0.60		

[a]The participation and distraction constructs were merged into one participation construct in this research study. These are the factor loadings for both constructs from the original survey implementation (i.e., DeMonbrun et al., 2017)

Appendix B. Survey 1 from Dissertation Study

CONSENT TO PARTICIPATE IN RESEARCH STUDY
An Examination of Student Response to Types of Instruction in the Engineering Discipline

Matt DeMonbrun, *Ph.D. Candidate, School of Education, University of Michigan*
Cindy Finelli, Ph.D, *Associate Professor, Electrical Engineering and Computer Science & Director, Engineering Education Research Program, University of Michigan*

Your class was selected to take part in a study on understanding student response to the types of instruction encountered in the engineering classroom. If you agree to be part of the research study, you will be asked to complete the following survey about your experiences with certain types of instruction prior to and during this course. The survey should take you approximately 10 minutes to complete.

For your participation in this study, you may choose to be entered into a random drawing for a $100 Amazon gift card (one gift card per class). If you are selected in the random drawing, you will be awarded the gift card approximately two weeks after the closing of this survey.

Participation in this study is completely voluntary. If you do not wish to participate in this study, you should not continue forward with completing the survey. You may skip any questions that you feel uncomfortable with answering. Because we would like to match your responses from this survey to a subsequent survey at end of the class, we ask you to fill out your e-mail address at the beginning of the survey. However, this data will never be used to personally identify your responses in any publications. At the end of the survey, you will have the option of having your e-mail address entered for the random drawing

For each question on the attached survey, please check the box that most closely matches your experience. Thank you for taking the time to complete the survey. If you have questions about this research, you may contact Matt DeMonbrun at mdemonbr@umich.edu.

By clicking the forward arrow, you consent to participate in this research study.

Please enter your @umich.edu e-mail address below:
(Note: this information will never be used to personally identify your responses in any publications)

Please indicate your gender:

- ❍ Male
- ❍ Female
- ❍ Transgender/Genderqueer
- ❍ Other ____
- ❍ I prefer not to respond.

Are you (Mark all that apply):

- ❑ White/Caucasian
- ❑ African American/Black
- ❑ American Indian/Alaska Native
- ❑ East Asian (e.g., Chinese, Japanese, Korean, Taiwanese)
- ❑ Filipino
- ❑ Southeast Asian (e.g., Cambodian, Vietnamese, Hmong)
- ❑ South Asian (e.g., Indian, Pakistani, Nepalese, Sri Lankan)
- ❑ Other Asian
- ❑ Native Hawaiian/Pacific Islander
- ❑ Mexican American/Chicano
- ❑ Puerto Rican
- ❑ Other Latino
- ❑ Other ____
- ❑ I prefer not to respond.

Please indicate your year in college:

- ❍ First
- ❍ Second
- ❍ Third
- ❍ Fourth
- ❍ Fifth or more

Citizenship Status (Mark one):

- ❍ U.S. Citizen
- ❍ Permanent Resident (green card)
- ❍ International Student (F-1, J-1, M-1, or other visa)
- ❍ I prefer not to respond.

What is your current GPA?:

- ❍ 3.5 or higher
- ❍ 3.0 to 3.49
- ❍ 2.5 to 2.99
- ❍ 2.0 to 2.49
- ❍ 0 to 1.99

What is your current/intended major (check all that apply)?

- ❑ Aerospace Engineering
- ❑ Biomedical Engineering
- ❑ Chemical Engineering
- ❑ Civil Engineering
- ❑ Climate and Meteorology
- ❑ Computer Engineering
- ❑ Computer Science
- ❑ Data Science
- ❑ Electrical Engineering
- ❑ Engineering Physics
- ❑ Environmental Engineering
- ❑ Industrial and Operations Engineering
- ❑ Materials Science and Engineering
- ❑ Mechanical Engineering
- ❑ Naval Architecture and Marine Engineering
- ❑ Nuclear Engineering and Radiological Sciences
- ❑ Space Science and Engineering
- ❑ Other ____

Please select the course which asked you to complete this survey?

- ❍ BIOMEDE 231
- ❍ CHE 330
- ❍ EECS 215
- ❍ EECS 280
- ❍ MECHENG 211

Did you take at least one engineering course in the past semester (Fall 2016)?

- ❍ Yes
- ❍ No

Please type in the name of the engineering course you took in Fall 2016 below. **If you took more than one engineering course in the Fall 2016 semester, please pick the one that is most relevant to the course which has asked you to complete this survey.**

- ❍ Course Name ____

For your course, did the instructor ever ask you to **discuss concepts with classmates during class**?

- ❍ Yes
- ❍ No

For your course, when the instructor asked you to **discuss concepts with classmates during class**, how often did you react in the following ways?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
I disliked the activity.					
I felt positively towards the instructor because of the activity.					
I enjoyed the activity.					
I complained to other students about the activity.					
I surfed the internet, checked social media, or did something else instead of doing the activity.					
I distracted my peers during the activity.					
I pretended to participate in the activity.					
I tried my hardest to do a good job with the activity.					
I did not actually participate in the activity.					
I gave the activity minimal effort.					
I felt the effort it took to do the activity was worthwhile.					
I saw the value in the activity.					
I felt the time used for the activity was beneficial.					

For your course, did the instructor ever ask you to **brainstorm different possible solutions to a given problem**?

- ❍ Yes
- ❍ No

For your course, when the instructor asked you to **brainstorm different possible solutions to a given problem**, how often did you react in the following ways?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
I disliked the activity.					
I felt positively towards the instructor because of the activity.					
I enjoyed the activity.					
I complained to other students about the activity.					
I surfed the internet, checked social media, or did something else instead of doing the activity.					
I distracted my peers during the activity.					
I pretended to participate in the activity.					
I tried my hardest to do a good job with the activity.					
I did not actually participate in the activity.					
I gave the activity minimal effort.					
I felt the effort it took to do the activity was worthwhile.					
I saw the value in the activity.					

For your course, were you ever asked to **answer questions posed by the instructor during class**?

- ❍ Yes
- ❍ No

For your course, when you were asked to **answer questions posed by the instructor during class**, how often did you react in the following ways?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
I disliked the activity.					
I felt positively towards the instructor because of the activity.					
I enjoyed the activity.					
I complained to other students about the activity.					
I surfed the internet, checked social media, or did something else instead of doing the activity.					
I distracted my peers during the activity.					
I pretended to participate in the activity.					
I tried my hardest to do a good job with the activity.					
I did not actually participate in the activity.					
I gave the activity minimal effort.					
I felt the effort it took to do the activity was worthwhile.					
I saw the value in the activity.					

For your course, were you ever asked to **listen to the instructor lecture during class**?

- ❍ Yes
- ❍ No

For your course ${Q9/ChoiceTextEntryValue/1}, when you **listened to the instructor lecture during class**, how often did you react in the following ways?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
I disliked the activity.					
I felt positively towards the instructor because of the activity.					
I enjoyed the activity.					
I complained to other students about the activity.					
I surfed the internet, checked social media, or did something else instead of doing the activity.					
I distracted my peers during the activity.					
I pretended to participate in the activity.					
I tried my hardest to do a good job with the activity.					
I did not actually participate in the activity.					
I gave the activity minimal effort.					
I felt the effort it took to do the activity was worthwhile.					
I saw the value in the activity.					

For each of the following types of instruction, please indicate how often you have done this so far **in this course.**

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
Listen to the instructor lecture during class.					
Brainstorm different possible solutions to a given problem.					
Find additional information not provided by the instructor to complete assignments.					
Work in assigned groups to complete homework or other projects.					
Make individual presentations to the class.					
Be graded on my class participation.					
Study course content with classmates outside of class.					
Assume responsibility for learning material on my own.					
Discuss concepts with classmates during class.					
Make and justify assumptions when not enough information is provided.					
Get most of the information needed to solve the homework directly from the instructor.					

Be graded based on the performance of my group.					
Preview concepts before class by reading, watching videos, etc.					
Solve problems in a group during class.					
Solve problems individually during class.					
Answer questions posed by the instructor during class.					
Ask the instructor questions during class.					
Take initiative for identifying what I need to know.					
Watch the instructor demonstrate how to solve problems.					
Solve problems that have more than one correct answer.					
Do hands-on group activities during class.					

Thank you for your responses! To be entered in the drawing for the $100 Amazon gift card, please check the box below.

- ❑ Yes, I would like to be entered into this drawing.

Appendix C. Survey 2 from Dissertation Study

CONSENT TO PARTICIPATE IN RESEARCH STUDY
An Examination of Student Response to Types of Instruction in the Engineering Discipline

Matt DeMonbrun, *Ph.D. Candidate, School of Education, University of Michigan*
Cindy Finelli, Ph.D, *Associate Professor, Electrical Engineering and Computer Science & Director, Engineering Education Research Program, University of Michigan*

Your class was selected to take part in a study on understanding student response to the types of instruction encountered in the engineering classroom. If you agree to be part of the research study, you will be asked to complete the following survey about your experiences with certain types of instruction during this course. The survey should take you approximately 10 minutes to complete.

For your participation in this study, you will receive a $10 Amazon gift card, which will be awarded to you approximately two weeks after the closing of this survey.

Participation in this study is completely voluntary. If you do not wish to participate in this study, you should not continue forward with completing the survey. You may skip any questions that you feel uncomfortable with answering. Because we would like to match your responses from this survey to a prior survey at beginning of the semester, we ask you to fill out your e-mail address at the end of this survey. However, this data will never be used to personally identify your responses in any publications. Your e-mail address will also serve as the primary contact method for receiving your gift card.

For each question on the attached survey, please check the box that most closely matches your experience. Thank you for taking the time to complete the survey. If you have questions about this research, you may contact Matt DeMonbrun at mdemonbr@umich.edu.

By clicking the forward arrow, you consent to participate in this research study.

What is your expected grade in this course

- A+/A
- A-
- B+
- B
- B-
- C+
- C
- C-
- D or below

About how frequently did you attend this lecture this semester?

- Always (100% of the time)
- Most of the time (75% of the time)
- About half the time (50% of the time)
- Sometimes (25% of the time)
- Never

In this course, were you ever asked to **discuss concepts with classmates during class**?

- ❍ Yes
- ❍ No

In this course, when the instructor asked you to **discuss concepts with classmates during class**, how often did you react in the following ways?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
I disliked the activity.					
I felt positively towards the instructor because of the activity.					
I enjoyed the activity.					
I complained to other students about the activity.					
I surfed the internet, checked social media, or did something else instead of doing the activity.					
I distracted my peers during the activity.					
I pretended to participate in the activity.					
I tried my hardest to do a good job with the activity.					
I did not actually participate in the activity.					
I gave the activity minimal effort.					
I felt the effort it took to do the activity was worthwhile.					
I saw the value in the activity.					

End of Block: Response to Activities 1

Start of Block: Response to Activities 2

In this course, were you ever asked to **brainstorm different possible solutions to a given problem?**

- ❍ Yes
- ❍ No

In this course, when the instructor asked you to **brainstorm different possible solutions to a given problem**, how often did you react in the following ways?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
I disliked the activity.					
I felt positively towards the instructor because of the activity.					
I enjoyed the activity.					
I complained to other students about the activity.					
I surfed the internet, checked social media, or did something else instead of doing the activity.					
I distracted my peers during the activity.					
I pretended to participate in the activity.					
I tried my hardest to do a good job with the activity.					
I did not actually participate in the activity.					
I gave the activity minimal effort.					
I felt the effort it took to do the activity was worthwhile.					
I saw the value in the activity.					

In this course, were you ever asked to **answer questions posed by the instructor during class?**

- ❍ Yes
- ❍ No

In this course, when you were asked to **answer questions posed by the instructor during class**, how often did you react in the following ways?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
I disliked the activity.					
I felt positively towards the instructor because of the activity.					
I enjoyed the activity.					
I complained to other students about the activity.					
I surfed the internet, checked social media, or did something else instead of doing the activity.					
I distracted my peers during the activity.					
I pretended to participate in the activity.					
I tried my hardest to do a good job with the activity.					
I did not actually participate in the activity.					
I gave the activity minimal effort.					
I felt the effort it took to do the activity was worthwhile.					
I saw the value in the activity.					

In this course, did you ever **watch the instructor lecture during class?**

- ❍ Yes
- ❍ No

In this course, when you were asked to **watch the instructor lecture during class**, how often did you react in the following ways?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
I disliked the activity.					
I felt positively towards the instructor because of the activity.					
I enjoyed the activity.					
I complained to other students about the activity.					
I surfed the internet, checked social media, or did something else instead of doing the activity.					
I distracted my peers during the activity.					
I pretended to participate in the activity.					
I tried my hardest to do a good job with the activity.					
I did not actually participate in the activity.					
I gave the activity minimal effort.					
I felt the effort it took to do the activity was worthwhile.					
I saw the value in the activity.					

In this course, did you ever **watch the instructor demonstrate how to solve problems?**

- ❍ Yes
- ❍ No

In this course, when you were asked to **w**atch the instructor demonstrate how to solve problems, how often did you react in the following ways?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
I disliked the activity.					
I felt positively towards the instructor because of the activity.					
I enjoyed the activity.					
I complained to other students about the activity.					
I surfed the internet, checked social media, or did something else instead of doing the activity.					
I distracted my peers during the activity.					
I pretended to participate in the activity.					
I tried my hardest to do a good job with the activity.					
I did not actually participate in the activity.					
I gave the activity minimal effort.					
I felt the effort it took to do the activity was worthwhile.					
I saw the value in the activity.					

In this course, did you ever **get most of the information needed to solve the homework directly from the instructor?**

❍ Yes

❍ No

In this course, when you had to **get most of the information needed to solve the homework directly from the instructor**, how often did you react in the following ways?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
I disliked the activity.					
I felt positively towards the instructor because of the activity.					
I enjoyed the activity.					
I complained to other students about the activity.					
I surfed the internet, checked social media, or did something else instead of doing the activity.					
I distracted my peers during the activity.					
I pretended to participate in the activity.					
I tried my hardest to do a good job with the activity.					
I did not actually participate in the activity.					
I gave the activity minimal effort.					
I felt the effort it took to do the activity was worthwhile.					
I saw the value in the activity.					

In this course, did you ever have to **take initiative for identifying what you needed to know?**

- ❍ Yes
- ❍ No

In this course, when you had to **take initiative for identifying what you needed to know**, how often did you react in the following ways?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
I disliked the activity.					
I felt positively towards the instructor because of the activity.					
I enjoyed the activity.					
I complained to other students about the activity.					
I surfed the internet, checked social media, or did something else instead of doing the activity.					
I distracted my peers during the activity.					
I pretended to participate in the activity.					
I tried my hardest to do a good job with the activity.					
I did not actually participate in the activity.					
I gave the activity minimal effort.					
I felt the effort it took to do the activity was worthwhile.					
I saw the value in the activity.					

In this course, were you ever asked to **preview concepts before class by reading, watching videos, etc.?**

- ❍ Yes
- ❍ No

In this course, when the instructor asked you to **preview concepts before class by reading, watching videos, etc.**, how often did you react in the following ways?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
I disliked the activity.					
I felt positively towards the instructor because of the activity.					
I enjoyed the activity.					
I complained to other students about the activity.					
I surfed the internet, checked social media, or did something else instead of doing the activity.					
I distracted my peers during the activity.					
I pretended to participate in the activity.					
I tried my hardest to do a good job with the activity.					
I did not actually participate in the activity.					
I gave the activity minimal effort.					
I felt the effort it took to do the activity was worthwhile.					
I saw the value in the activity.					

In this course, when the instructor asked you to do in-class, non-lecture activities (e.g., solve problems in a group during class or discuss concepts with classmates), how often did ***the instructor*** do the following things?

	Almost never (	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very often (>90% of the time)
Clearly explained what I was expected to do for the activities.					
Clearly explained the purpose of the activities.					
Discussed how the activities related to my learning.					
Solicited my feedback or that of other students about the activities.					
Used activities that were the right difficulty level (not too easy, not too difficult).					
Walked around the room to assist me or my group with the activities, if needed.					
Encouraged students to engage with the activities through his/her demeanor.					
Gave me an appropriate amount of me to engage with the activities.					
Confronted students who were not participating in the activities.					
Invited students to ask questions about the activities.					

Please enter your @umich.edu e-mail address below:
(Note: this information will never be used to personally identify your responses in any publications)

____

Thank you for your responses! You will be contacted approximately two weeks after this survey closes for information on collecting your gift card.