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After the workshop: A study of engineering instructors' post-workshop implementation of active learning in the classroom

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Dedication

I dedicate this dissertation to every student in the world who is eager to learn and bring change through education. I wish them with courage, hope and strength to overcome economic, social and administrative barriers on their path to learning.

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After the workshop: A study of engineering instructors' post-workshop implementation of active learning in the classroom

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Existing engineering education research has empirically validated the effectiveness of active learning over traditional instructional methods. Faculty development workshops have been initiated to promote adoption of active learning to engineering classrooms. Although researchers have examined the effectiveness of engineering faculty development workshops, most of the research has relied on faculty self-report. Self-report often limits the examination of various features that influence teaching such as faculty conceptions, student response to instruction and faculty development experiences. In this study, using classroom observations, instructor interview, student focus groups and surveys, I examined two engineering instructors' post-workshop implementation of active learning in the classroom. The findings demonstrate the influence of faculty conceptions of teaching in selection and design of activities and subsequent impact of these design choices on student engagement. I report the instructors' and students' responses to the active learning exercises and present recommendations for engineering faculty development.

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I. Chapter One: Introduction

Recently, learner-centered teaching or active learning approaches have received considerable attention in engineering education. For the purpose of this study, learner-centered teaching, or active learning, is defined as a type of instruction that allows students to participate in the learning process by engaging them in meaningful activities during the classroom session (Bonwell & Eison, 1991; Prince, 2004). Learner-centered and active learning approaches fall under the broad category of inductive teaching and learning. Usually, the teaching approach in engineering is deductive involving an introduction to topics and underlying principles through lecture, then derivation of mathematical models and finally application of these models in homework problems (Prince & Felder, 2006). On the other hand, the active learning or inductive approach begins with a set of observations or a complex real-world problem. In the process of solving the given problem or analyzing the observations, the student themselves generate procedures and guiding principles (Prince & Felder, 2006).

Active learning places emphasis on the constructivist conception of learning where the primal aim is that "the learner can elaborate on applications of knowledge and s/he may also produce new knowledge using cognitive processes" (Niemi, 2002, p. 764). The focus on active learning-based instruction has been driven by the need to ensure alignment between student learning outcomes and performance characteristic needed in future engineers (National Academy of Engineering, 2005). Along with disciplinary knowledge and competence, engineering graduates should possess skills that allow them to work effectively in workplace environments (Gibbings, Lidstone, & Bruce, 2008). Engineers are hired for their ability to solve problems. However, most engineering graduates lack the skills to solve complex problems which often possess conflicting goals, and multiple solution methods (Jonassen, Strobel, & Lee, 2006).

Engineering as the discipline undergoes continuous evolution as it adapts to new knowledge, technology and needs of society. In order to meet the demands of this rapidly evolving field, future engineers need to possess attributes like analytical skills, creativity, ingenuity, professionalism and leadership (National Academy of Engineering, 2004). The Accreditation Board for Engineering and Technology (ABET) has identified the ability to identify, formulate, and solve workplace engineering problems as one of the most important skills that engineers should possess (ABET, 2012).

The National Academy of Engineering (2005) has recommended key elements for inclusion in an engineering education system, such as, application of engineering processes to define and solve problems, engagement of engineers in multidisciplinary teams and interaction of engineers with customers and with the public. The report also emphasized on the importance of alignment of engineering curricula and experiences with future workplace challenges. Specifically, along with technical knowledge, “graduates should also possess team, communication, ethical reasoning, and societal and global contextual analysis skills as well as understand work strategies” (National Academy of Engineering, 2005, p. 52). To promote the attainment of these skills in engineering graduates, ABET reformed its accreditation standards to focus of assessment of learning outcomes that engineering should possess upon graduation (ABET, 2012; Galloway, 2007). This change to outcome-based accreditation has contributed towards alignment of courses and programs with the new standards that accommodate the required professional and technical skills (Lattuca, Terenzini, & Volkwein, 2006). Furthermore, ABET is considering revision of the existing criteria to better align with the skills needed in engineering graduates. Active learning facilitates the adoption of such skills in engineering graduates(Felder, Woods, Stice, & Rugarcia, 2000; Rugarcia, Felder, Woods, & Stice, 2000).

Faculty members play a crucial role in enhancing student learning experiences in an institutional setting due their direct interaction with students (Chen, Lattuca, & Hamilton, 2008).
To develop the desired skills in engineering graduates, researchers have recommended pedagogical change from traditional instructional approaches to active learning-based teaching for engineering faculty members (Prince, 2004). Active learning classroom approaches improve critical thinking skills when compared to lecture based instruction (Felder, 2012; Felder et al., 2000; Rugarcia et al., 2000). In addition to improving learning outcomes, active learning methods that engage students in the classroom increase retention of students in STEM disciplines (PCAST, 2012). In engineering education, extensive existing research has empirically validated the effectiveness of various types of active learning over traditional instructional methods (Felder, 1995; Felder et al., 2000; Freeman et al., 2014; Iscioglu & Kale, 2010; Johnson, 1999; Montero & Gonzalez, 2009; Prince, 2004; Prince & Felder, 2007; Yadav, Subedi, Lunderberg, & Bunting, 2011).

In spite of this strong empirical support for the effectiveness of active learning, the adoption of active learning in engineering classrooms has been slow (Jamieson & Lohmann, 2012; PCAST, 2012). Existing research has indicated the frequent use of lecture-based instruction by STEM faculty members (Walczyk & Ramsey, 2003). In addition, researchers have reported that engineering instructors often tend to use lecture-based instruction more than active learning in their classrooms (Lindblom-Ylänne, Trigwell, Nevgi, & Ashwin, 2006). In order to improve engineering education it is necessary to “catalyze widespread adoption of empirically validated teaching practices” (PCAST, 2012, p. 2). Thus, to facilitate this adoption, research focus should shift from finding more effective instructional strategies to promoting the use of already known student centered instructional strategies in engineering classrooms (Prince, Borrego, Henderson, Cutler, & Froyd, 2014).

Faculty members often lack awareness about evidence-based active learning methods due lack of formal training (Bransford, Brown, & Cocking, 1999; Felder, Brent, & Prince, 2011; Fox & Hackerman, 2002; PCAST, 2012; Tanner & Allen, 2006). However, after undergoing pedagogical training, they are “likely to consult sources of instructional innovation and consider teaching an important part of their professional identities” (Walczyk, Ramsey, & Zha, 2007, p. 85). To spread awareness about active learning among engineering faculty and bridge the gap between research and practice, engineering education experts have recommended faculty development programs to provide training and support about application of active learning to current and future faculty (Felder et al., 2011; Jamieson & Lohmann, 2012; PCAST, 2012).

Consequently, faculty development programs have been initiated in engineering (Felder & Brent, 2010) and well as other STEM disciplines (Henderson, 2008). The implementation of the revised ABET accreditation standards has increased involvement in teaching-related professional activities by engineering faculty members (Lattuca et al., 2006). In addition, researchers have indicated that students of faculty members who participated in professional development reported greater analytical skills than the students with programs where the instructors had less exposure to professional development (Lattuca et al., 2006).

In summary, with the emergence of engineering education research as an internationally connected field of inquiry (Borrego & Bernhard, 2011), there have been “growing incentives for engineering faculty members to engage in the scholarship of teaching and learning” (Felder et al., 2011, p. 92). However, the dissemination of engineering education research into instructional practice has been slow (Jamieson & Lohmann, 2012; PCAST, 2012). Faculty development workshop programs offer a solution to promote widespread adoption of research-driven instructional strategies in engineering classrooms. In fact, researchers have suggested that faculty development programs have a positive influence on promoting awareness and interest and thus promoting pedagogical change in engineering classrooms (Felder & Brent, 2010; Lattuca, Bergom, & Knight, 2014). However, most of the existing engineering education research has relied on faculty self-report to evaluate the success of faculty development programs (e.g. Felder & Brent, 2010; Lattuca et al., 2014). The researchers have themselves expressed the limitations of their studies due to reliance on self-report data, encouraging further inquiry in this area (Froyd, Borrego, Cutler, Prince, & Henderson, 2013; Lattuca et al., 2014). Guided by this gap in literature, in this study, I examined two engineering instructors’ post-workshop implementation of active learning in their classrooms.

Purpose of the study

Researchers have found that faculty self-report of pedagogical practices may differ significantly from classroom observation evidence (Ebert-May et al., 2011). There is a need to examine " how instructors use their knowledge of educational innovations and situational constraints to arrive at practical decisions in the moment-to-moment demands of the classroom" (Turpen & Finkelstein, 2009, p. 14). In engineering education, there is a paucity of research examining the dynamics of such active learning episodes (Chen et al., 2008). Most of existing engineering education research has relied on faculty self-report to examine the use of active learning (e.g. Borrego, Froyd, & Hall, 2010; Felder & Brent, 2010; Froyd et al., 2013; Lattuca et al., 2014; Prince et al., 2014). The purpose of this study is to examine engineering instructors' post-faculty development workshop implementation of active learning in the classroom. The research questions include:

1) How does an instructor implement active learning after attending a workshop?
2) How does an instructor select and design active learning exercises?
3) What challenges does the instructor face in the design and use of active learning?
4) How do students respond to the use of active learning?

II. Chapter Two: Literature Review

Recent educational reform efforts have resulted in increased awareness about educational research among STEM faculty members. Dancy and Henderson (2010) reported findings of a survey study comprising 722 physics faculty in the US. The researchers reported high levels of awareness of research-informed curricula and instruction among the faculty members. In addition, the findings suggested that the instructors were motivated towards incorporating the pedagogies in their teaching. However, in spite of high awareness and interest, the level of actual pedagogical change reported by the instructors was not significant (Dancy & Henderson, 2010).

In engineering, although there have been "growing incentives for engineering faculty members to engage in the scholarship of teaching and learning" (Felder et al., 2011, p. 92), the dissemination of engineering education research into instructional practice has been slow. Recent calls from the National Science Foundation have further emphasized the importance of research focusing on adoption of research-driven teaching practices such as active learning (NSF, 2015). Froyd et al. (2013) conducted a study examining Electrical and Computer Engineering faculty's use of various active learning strategies. The survey consisted of 12 different types of active learning and asked the faculty to indicate their level of knowledge and use for each listed types. Based on the findings, the researchers concluded that certain active learning types were more likely to be used by faculty members who either attended workshops or engaged in discussion about their teaching. Faculty development workshops programs offer a solution to promote widespread adoption of active learning in engineering classrooms.

Faculty Development Programs

Faculty development programs aid in increasing instructors' pedagogical knowledge and thus promote the use of active learning (Lattuca et al., 2014). Faculty development workshops are more likely to have a larger impact if they are conducted by educational experts with the same disciplinary backgrounds as that of the participant faculty members (Felder et al., 2011), i.e., engineering. Several workshops on engineering education are being offered by engineering professional societies including American Institute of Chemical Engineers, Mexican institute of Chemical Engineering and American Society for Engineering Education (Stice, Felder, Woods, & Rugarcia, 2000).

Although faculty development programs have been offered in engineering, the need "has taken on new urgency in the past two decades" (Felder et al., 2011, p. 91). This urgency has emerged as a result of several culminating factors: introduction of outcomes-based program assessment, decline in engineering graduation rates, lack of equal demographic representation, change in needed engineering skills, development of instructional technology and advances in cognitive science (Felder et al., 2011).

Lattuca et al. (2014) examined the relationship between faculty professional development and engineering faculty members' use of student-centered instruction. The researchers surveyed 906 engineering faculty members from 31 four-year institutions in US. The results from the nationally representative sample indicated a significant positive relationships between participation in professional development workshops and faculty members' use of active learning-based instruction. The authors recommended departmental support for engineering instructors to increase the adoption of active learning in the classroom.

Although faculty development workshops generate awareness and interest among faculty members, this does not necessarily mean that workshop recommendations such as active learning are being faithfully translated into practice. Researchers have confirmed variation in faculty self-report of pedagogical practices from actual classroom observations. Ebert-May et al. (2011) conducted a study to measure extent of the use of learner-centered pedagogies by biology instructors after participating in a professional development workshop. The researchers used instructor surveys and classroom observations to investigate the variation in self-report and actual instructor practices. The instructor self-report data reported that the 89% of the participants used active learning in their classroom. On the other hand, the observational data showed discrepancy with instructor self-report with 75% of the participant faculty members using lecture-based, teacher- centered instruction.

In a another study, Turpen and Finkelstein (2009) examined the implementation of peer instruction in an introductory undergraduate physics course. The observational findings of this case study revealed variations in the implementation of peer instruction by different participant instructors. Specifically, the researchers reported variations in student engagement in tasks such as formulating and asking questions, evaluating solutions and interaction. The researchers suggested that these variations in practices lead to emphasis on certain aspects of the instruction over others. Although the basic tenets of student engagement in peer instruction such as student discussion and application of concepts were met, the instructors' practices created implementation sub-types with different pedagogical implications. The researchers argued that the variations were due to instructors' conceptions and suggested the need to examine the ways in which "instructors use their knowledge of educational innovations and situational constraints to arrive at practical decisions in the moment-to-moment demands of the classroom." (Turpen & Finkelstein, 2009, p. 14).

Instructional practices are complex and not a function of strict demarcations (Hora & Ferrare, 2014). The design of courses, choice of content and the influence of faculty development experiences are important factors effecting student learning (Chen et al., 2008). Faculty self-reports primarily relies on instructors to report their instruction type based on the prepopulated list of pedagogical types (e.g. Froyd et al., 2013; Lattuca et al., 2014; Prince et al., 2014). The association of instructional practices solely with a defined pedagogical type limits the examination of various features that are part of the teaching (Hora & Ferrare, 2013). Thus, these self-reports often fail to capture the differences in the way active learning is used in the classroom. For example, faculty self-report of use of active learning will confirm an increase in adoption, but will not answer questions examining implementation subtleties such as the type of questions asked during discussions and the cognitive quality of posed problems.

In summary, college instructors are usually unfamiliar with educational research and its pedagogical implications (Marra, 2005). Faculty development workshops intend to bridge this gap by providing formal training to instructors about research based instructional practices. Existing research has primarily relied on self-report to investigate instructional change in engineering classrooms (Felder & Brent, 2010; Froyd et al., 2013; Lattuca et al., 2014; Prince et al., 2014). Researchers have reported variations between instructor self-report and actual classroom practices (Ebert-May et al., 2011; Turpen & Finkelstein, 2009). There is a paucity of research examining the dynamics associated with the implementation of active learning in actual classrooms (Chen et al., 2008). However, almost no prior research has been done to study the teaching practices of engineering instructors after participating in a faculty development workshop. Guided by this gap in literature, in this study, I examined two engineering instructors' implementation of active learning after attending National Effective Teaching Institute workshop.

National Effective Teaching Institute

The National Effective Teaching Institute (NETI) is a three day faculty development workshop conducted every year in conjunction with the ASEE's annual conference. The process of recruitment involves notification to engineering deans at various institutions across US and Canada to nominate up to two faculty members with at least one semester of teaching experience to attend the workshop. The acceptance to the workshop is on a first come, first served basis for the approximately 50 available seats, and the expenses are expected to be paid by the dean. The topics covered in the workshop cater to a wide range of curricular and instructional aspects such as instructional design, course planning, assessment and evaluation of learning, active learning, and time management. Since 1991, the 1312 faculty members from 244 different institutions have participated in the workshop (ASEE, 2015).

One of the key areas of focus of the workshop is to promote active learning. During the workshop, the conveners provide practical suggestions and discuss existing research on active learning. Some of these recommendations include: 1) selection of a few active learning types rather than attempting to implement every technique, 2) implementation of selected active learning techniques multiple times to understand how well they work, 3) trying one or two new techniques every semester, and 4) finding the best way to use active learning for their particular situation (Felder & Brent, 2010).

Felder and Brent (2010) conducted a study to evaluate the effectiveness of NETI in achieving its objectives. In the study, the researchers surveyed 607 alumni of the workshop with questions examining the impact of NETI on their instructional practices, student ratings, involvement in educational research and attitude about teaching and learning. The researchers reported that 98% of the participants occasionally or frequently used active learning. In addition, 74% of participants acknowledged that the NETI workshop either moderately or substantially influenced their use of active learning. Furthermore, the pre-post workshop survey showed significant increase in the awareness of active learning. Based on these findings, the researchers concluded that NETI was successful in increasing the awareness of various pedagogical aspects among the participants and was able to persuade them to adopt the active learning methods in their instruction.

Faculty members who attended NETI have presented their experiences, challenges and recommendations when implementing active learning in educational conferences including difficulty selecting activities (Reid, 1999) or student resistance to the activities (Ssemakula, 2001). For example, Reid (1999) described his post workshop experiences and mentioned that one of the difficulties encountered is to select a particular type of active learning for implementation in the classroom. In another example, Ssemakula (2001) reported the implementation of cooperative learning in a manufacturing processes course. In the paper, the author mentioned that:

> There was some resistance to this idea when first introduced but I persevered and at the end of the first semester, most students realized the value of the innovation and said that it helped them learn. With the experience gained, I was able to operate the cooperative learning groups more effectively in subsequent semesters (Ssemakula, 2001, p. 4).

While researchers have highlighted that instructional choices and practices are considerably affected by instructor's conceptions about teaching (Froyd, Layne, & Watson, 2006; Marra, 2005; Yerushalmi, Henderson, Heller, Heller, & Kuo, 2007), student resistance has been often cited as a major barrier towards adoption of active learning (Cutler, Borrego, Henderson, Prince, & Froyd, 2012; Dancy & Henderson, 2010; Finelli, Richardson, & Daly, 2013; Froyd et al., 2013; Prince et al., 2014). I argue that the influence of instructor's conceptions of teaching and contextual factors such as student resistance often lead to variations in the implementation of active learning in the classroom.

The conveners of the NETI workshop (Felder & Brent, 2010) and other researchers (Froyd et al., 2013) have acknowledged the existence of variations in implementation of various active learning types and also existence of student resistance to active learning. Researchers have noted that what faculty members are "actually doing in the classroom may not reflect the characteristics that the RBIS [Research Based Instructional Strategy] developer indicated should be used" (Froyd et al., 2013, p. 395). Researchers expressed limitations of their studies due to reliance on self-report data, encouraging further inquiry in this area (Froyd et al., 2013; Lattuca et al., 2014). Most of the existing engineering education research has relied on faculty self-report to evaluate the success of faculty development programs. In this study, I focus on examining the influence of instructors' conceptions of teaching and student resistance on the implementation of active learning in an engineering classroom after attending a faculty development workshop.

Conceptual Framework

Kember (1997) presented a model of teaching and learning describing the linkages between a faculty member's conceptions of teaching, teaching approaches and student outcomes. The model illustrated that a teaching approach chosen by an instructor is influenced by several institutional and classroom factors, leading to different student learning outcomes. The factors included faculty member's conceptions of teaching, student presage factors, curriculum design and institutional influence. The study provided evidence in support of the influence of these factors on teaching approaches. Reiterating the criticality of instructor's conceptions of teaching, the researcher noted that at individual level, the adopted teaching approaches were "strongly influenced by the orientation to teaching" (p. 270). These orientations were characterized on a continuum ranging from teacher-centered to student-centered instruction.

Although the model included the departmental influence as a factor governing the choice of teaching approach, the researchers expressed uncertainty about the ability of an institution to influence a faculty member's conceptions of teaching. Describing a faculty member's conceptions of teaching as a "complex amalgam of influences such as experiences as a student, departmental and institutional ethos, conventions of the discipline and even the nature of the classroom" (p.271), the researchers argued that educational development efforts may not lead to desired outcomes if faculty member's conceptions are not accounted for in the process.

To empower educational development initiatives, the researchers called for faculty development programs "which are cognizant of the significant influence of conceptions of teaching" (Kember, 1997, p. 272). Light, Calkins, Luna, and Drane (2009) conceptualized the influence of faculty development on teaching approaches and presented a modified model (Figure 2.1). The factors included faculty member's conceptions of teaching, faculty development, student presage factors, curriculum design and institutional influence. In this study, I examined how a faculty member's conceptions of teaching, student presage factors and faculty development workshop experience influences the use of active learning as a teaching approach in an engineering classroom.

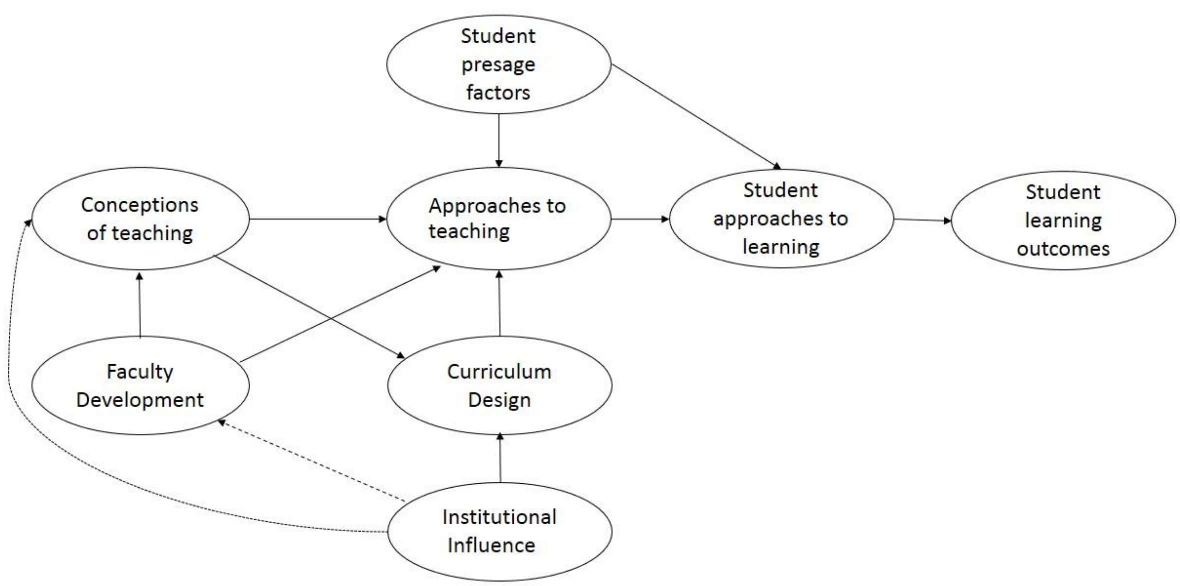

Figure 2.1 : Extended model of faculty development, teaching and learning (Light et al., 2009)

Instructor conceptions of teaching

College instructors are usually unfamiliar with educational research and its pedagogical implications (Marra, 2005). Faculty development workshops intend to bridge this gap by providing formal training to instructors about active learning. Researchers have argued that although instructors are able to incorporate several research-based pedagogical aspects into their instruction, there exists a lack of full adoption which is attributed to the influence of instructors' conceptions of teaching on the actual enactment of the research informed curricula (Henderson, Heller, Heller, Kuo, & Yerushalmi, 2002). In addition, research has suggested that the conceptions of teaching has considerable effect on instructional behaviors and practices (Marra, 2005). In this study, I used the following definition of instructor conceptions: "general mental structure that involves knowledge, ideas, beliefs, values, mental images, preferences, and similar aspects of cognition." (Yerushalmi et al., 2007, p. 1).

Kane, Sandretto, and Heath (2002) reviewed literature on college teachers' conceptions and practices and suggested that "an understanding of university teaching is incomplete without a consideration of teachers' beliefs about teaching and a systematic examination of the relationship between those beliefs and teachers' practices" (p. 182). Their review confirmed this gap in existing research and called for research that examines instructors' conceptions and self-report of their teaching in conjugation with direct observations of their teaching practices. Several researchers have advocated the dependence of instructors' choice of curricular material and pedagogy on their conceptions (Froyd et al., 2006; Yerushalmi et al., 2007).

Henderson and Dancy (2005) interviewed four physics faculty members about their beliefs about teaching and learning. The researchers reported that although instructors' conceptions were in alignment with physics education research, the instructors did not often employ active learning in their instruction. In addition, the researchers reported that the instructors often did not fully use the research-based curricula, rather they choose to implement parts of it based on their instructional and personal preferences.

In engineering, Borrego, Froyd, Henderson, Cutler, and Prince (2013) investigated the influence of instructor's teaching and learning conceptions on pedagogies. The researchers found that engineering instructors' conceptions were aligned with existing educational research, namely that students learn better when they solve problems. Yet, the instructors were reluctant to increase the amount of class time devoted to problem solving due to social norms and difficulty understanding how to implement group work.

In another study, Froyd et al. (2013) investigated the barriers to adoption of active learning in electrical and computer engineering courses and found that instructors' teaching conceptions were a more critical barrier than promotion and tenure. Approaches addressing these conceptions can benefit instructors in implementing active learning in engineering classrooms (Borrego et al., 2013). Several other STEM education researchers have advocated the importance of considering instructors' conceptions for effective faculty development (McAlpine & Weston, 2000; Yerrick, Parke, & Nugent, 1997; Yerushalmi et al., 2007). In this study, I examined the influence of instructors' conceptions on the use of active learning after attending a workshop.

Student presage factors

Student presage factors include predispositions that students bring into the classroom including preferred ways of learning (Biggs, 1989). These preferences "can act as a lens through which they see and experience learning activities" (Marra, 2005, p. 152). Students often perceive that active learning requires too much work when compared to traditional teaching methods (Jonassen, Marra, & Palmer, 2004). Marra (2005) argued that "when students' learning scripts are based on traditional, transmission modes of education, they might not experience the full benefits of constructivist learning environments or might even respond negatively to them" (p. 152). Active learning techniques often receive negative student response or student resistance due to mismatch with students' preferred ways of learning (Åkerlind & Trevitt, 1999; Alpert, 1991; Felder, 2007; Gaffney, Gaffney, & Beichner, 2010; Keeley, Shemberg, Cowell, & Zinnbauer, 1995; Weimer, 2013).

Cutler et al. (2012) surveyed 221 engineering instructors teaching electrical, computer and chemical engineering courses. The researchers reported that teaching workshops are influential in increasing instructors' knowledge about active learning. Although the findings showed that majority of the instructors were aware of active learning, the results also reported that 35% instructors who tried active learning have discontinued its use.

Henderson, Dancy, and Niewiadomska-Bugaj (2012) examined physics instructors' pedagogical knowledge and practices. The researchers found that knowledge and/or the use of active learning significantly correlated with teaching workshop participation. In addition, the researchers reported that approximately one-third of the instructors discontinued its use after trying one or more active learning techniques. In line with prior research (Dancy et al., 2010; Seymour, 2002), the researchers suggested that one of the reasons for discontinued use may be student resistance, which instructors might face when they implement active learning.

Examining systemic factors that influence the adoption of active learning, Dancy and Henderson (2005) reported student resistance as one of the factors hindering instructional change. Student resistance has been identified as a critical barrier to instructional change and discontinued use of active learning by researchers (Cutler et al., 2012; Dancy & Henderson, 2010; Finelli, Richardson, & Daly, 2013; Froyd et al., 2013; Prince et al., 2014) and engineering faculty developers (Felder, 2011; Felder & Brent, 1996, 2010).

Lake (2001) examined student performance and perceptions of lecture-based course in comparison to an active learning version of the course involving group discussions. The findings reported higher course grades for active learning course in comparison with the traditional lecture course. However, in spite of increase in student performance, the students' perceptions of the course and instructor's effectiveness were reported lower for active learning section when compared to the lecture section.

In a more recent study, Yadav et al. (2011) investigated the influence of Problem Based Learning (PBL) on students' learning in an undergraduate electrical engineering course. Based on performance on a skill-based test, the authors reported that students' learning gains from PBL were significantly better than traditional lecture-based learning. However, students' open ended responses showed that PBL caused discomfort among students.

In other words, students' often hold negative perceptions of active learning based on their experiences. Several researchers have reported students' negative responses to active learning due to concerns over increased workload (Ribeiro, 2005), lack of content coverage (Montero & Gonzalez, 2009) and lack of direct information from the instructor (Yadav et al., 2011). These student concerns highlight that instructors might face student resistance when they try to implement active learning in their classrooms.

Furthermore, faculty workshop conveners have also cautioned that attendees might receive negative response from students when they attempt to implement various workshop recommendations, which could negatively affect their teaching evaluations (Felder & Brent, 2010). This would discourage instructors to use active learning, especially the ones who have already been receiving positive response on their teaching evaluations (Felder & Brent, 2010). Thus, instructors' concerns about student resistance and students' reported negative perceptions of active learning make the examination of student resistance and its underlying causes a logical research step towards bringing empirically tested active learning-based instructional methods into practice.

Weimer (2013) categorized student resistance into three types: (1) passive, in which students do not engage in the activity; for instance, by not talking to their neighbors when asked to discuss a question, (2) partial compliance, in which students engage by giving minimal effort or by rushing through the activity; and (3) open resistance, in which students express verbal complains to the instructor, peers or other faculty members. Considering the lack of prior work, researchers have called for systematic examination of student resistance (Åkerlind & Trevitt, 1999). For such systematic examination, investigators should distinguish recurring patterns from temporary instances (Alpert, 1991) and collect evidence in terms of percentage of disengaged students during the activity (Seidel & Tanner, 2013). The next section presents a review of existing protocols that were developed to examine the implementation of active learning in the classroom.

Review of existing protocols

The Reformed Teaching Observation Protocol (RTOP), developed by Sawada et al. (2002), has been widely used in K-12 education research, particularly by researchers interested in active learning practices (Adamson et al., 2003; Judson & Lawson, 2007; MacIsaac & Falconer, 2002). The 25-item observation tool allows quantitative measurement of the degree to which active learning has been incorporated in practice. The 25 items were divided into three categories: (1) Lesson Design and Implementation, (2) Content and (3) Classroom Culture. The Classroom Culture items were further categorized into Communicative Interactions and Student/Teacher relationships. Guided by their primary question, "How would you know if a mathematics or science classroom was reformed?" (p. 246), the protocol focuses primarily on the instructor rather than the students. The focus on the instructor and K-12 settings limits the applicability of this protocol to a study of undergraduate student resistance.

Walkington et al. (2011) developed the UTeach Observation Protocol (UTOP) to evaluate mathematics and science teachers from the UTeach teacher preparation program. The researchers motivated the need for this protocol by arguing that the RTOP lays little emphasis on the accuracy and depth of lesson content. The UTOP included 32 classroom indicators categorized into four sections: Classroom Environment, Lesson Structure, Implementation and Math/Science Content. This protocol also focuses on K-12 and may have limited use in undergraduate classrooms.

Specific to postsecondary classrooms, Wainwright, Flick, and Morrell (2003) developed the Oregon Collaborative for Excellence in the Preparation of Teachers Classroom Observation Protocol (OTOP). Arguing against the appropriateness of directly using observation tools developed for K-12 classrooms (RTOP) in college level studies, the authors developed the protocol to document the influence of instructors' participation in teacher preparation programs on their instructional design and practice. In addition, the researchers asserted that "observations of teaching should …include not just teacher actions, but also student behaviors" (p. 27). Unlike RTOP where the primary focus was on the instructor, OTOP placed equal emphasis on both teacher and student behaviors. However, the protocol did not address student resistance in detail.

Following a similar student centric approach, Hora and Ferrare (2013) designed the Teaching Dimension Observation Protocol (TDOP) to capture the interaction between students, instructors and other artifacts in an undergraduate classroom. Although TDOP places equal emphasis on both instructor and student, the coding rules developed for the cognitive engagement section do not fully capture student engagement. For example, the code representing "connect to real world" was applied when "the instructor linked the course material to events …… associated with popular culture or the state or city where the institution was located through anecdotes or extended illustrations" (p. 227). Similarly, the "understanding problem solving" code was applied when "instructors verbally directed students to participate in a computation or other problem solving activity" (p. 227). In other words, although the TDOP brings new emphasis to student engagement, the focus is still through ways the instructor seeks to engage students rather than the students' reaction.

Smith et. al. (2013) developed The Classroom Observation Protocol for Undergraduate STEM (COPUS) to characterize the use of active learning in college classrooms. Being an adaptation of TDOP, the COPUS protocol placed equal emphasis on students and the instructor. The protocol used codes (Listening to Instructor/Taking Notes (L), Student asks Questions (SQ), Presentation by students (SP), etc.) to report what the instructor and the students were doing during the class session. However, the protocol focused on capturing positive student reactions rather than passive or negative reactions that would signify student resistance.

In an engineering education focused example, Harris and Cox (2003) described the development of an observation protocol, the "VaNTH Observation System," designed to quantitatively indicate the differences in teaching and learning experiences in a biomedical engineering classroom. Guided by the How People Learn (HPL) theory, the researchers utilized the proposed four-part observation system to capture the instructional differences between HPL and traditional classrooms. The four parts of the system include: (1) Classroom Interaction Observation, (2) Student Engagement Observation, (3) Narrative Notes, and (4) Global Ratings. The Student

Engagement Observation section specifically caters to students' desired and undesired behaviors in a classroom. The researchers modified their HPL based K-12 model to make the protocol appropriate for college level observation. Specifically, a new category of "off-task with media" was added to address the undesirable use of personal computers in the classroom. Also, student engagement was refined from "yes" or "no" to "possibly engaged" and "definitely engaged". Observers relied on the extent of student note-taking and listening to determine whether students were possibly or definitely engaged. Thus, the protocol was able to capture student behavior in a college level classrooms. However, I argue that since note-taking and passive listening may indicate student disengagement more than engagement in an active learning-based classroom, the protocol is not appropriate for observing student resistance.

In summary, although the existing observation protocols cater to nontraditional teaching practices, they cannot be directly applied for observing student resistance to active learning in engineering classrooms because: (a) the protocols have been designed for K-12 classrooms (e.g. Sawada et al., 2002; Walkington et al., 2011); (b) the protocols focus more on instructor than student behavior (e.g.Erdle & Murray, 1986; Hora & Ferrare, 2013); or (c) the protocol does not sufficiently capture student resistance (e.g. Harris & Cox, 2003; Smith, Jones, Gilbert, & Wieman, 2013; Wainwright et al., 2003). In this study, I used the observation protocol developed by Shekhar et al. (2015) to study undergraduate engineering student resistance to active learning. The observation protocol is described in detail in the Methods section.

Table 2.1: Summary Characteristics of Previous Classroom Observation Protocols

Protocol	Level (K-12, UG)	Student/instructor focus	Detail about student reactions	Key reference	STEM application references
RTOP	K-12	Primarily on instructor	Student communicative interactions	Hora and Ferrare (2013)	Adamson et al. (2003); Judson and Lawson (2007); MacIsaac and Falconer (2002)
UTOP	K-12	Instructor only	None	Walkington et al. (2011)	Walkington and Marder (2013)
OTOP	UG	Both student and instructor	Student Discourse and collaboration	Wainwright et al. (2003)	Wainwright, Morrell, Flick, and Schepige (2004)
TDOP	UG	Both student and instructor	Limited focus on student engagement	Hora and Ferrare (2013)	Hora, Ferrare, and Oleson (2012)
COPUS	UG	Both student and instructor	Only positive student reactions	Smith et. al. (2013)	Smith et al. (2013)
VOS	UG	Primarily on instructor	Only note-taking and listening as indicators of student engagement	Harris and Cox (2003)	Cox and Cordray (2008)

Summary

To summarize, instructors' conceptions of teaching and student resistance are important factors influencing the use of active learning. Researchers have pointed out misalignment in the implementation of active learning with the intended use described by the developer as a related reason for discontinued use of active learning (Henderson et al., 2012). When instructors use active learning, "they usually do not follow or even necessarily learn about all of the details of innovation use described by the developer" (Henderson et al., 2012, p. 11). This reinvention may omit essential pedagogical features and aggravate student resistance in response to the used active learning. Although teaching workshops yield progressive results in disseminating research-driven teaching practices, additional support is required in facilitating its continued use (Henderson et al., 2012). Thus, to promote the effective use of active learning in the classroom, the influence of instructors' conceptions of teaching and student resistance on teaching practices should be examined.

The implementation of active learning by an engineering faculty development workshop participant has received minimal empirical, conceptual and analytic attention. There is a need of following a cyclical approach for faculty development where the research-informed teaching is used to further inform research (Adams & Felder, 2008). One recommended approach is to provide feedback to education practitioners on their research-informed instruction (Adams & Felder, 2008). In this study, using classroom observations, instructor interview, student focus groups and survey, I report the examination of two engineering instructors' post-workshop use of active learning.

III. Chapter Three: Methodology

Introduction

A case study approach is used in qualitative research when the research is focused on understanding an event by answering the “how” and “why” questions (Yin, 2003). Existing research on post faculty development workshop experiences has primarily relied on self-report surveys to measure the extent of use of active learning in classroom. In this study, I used a case study approach to examine how two instructors implement active learning after participating in a faculty development workshop.

Qualitative research methods allow researchers to gain new insights about the nature of certain situations and develop new concepts about a phenomenon or event (Borrego, Douglas, & Amelink, 2009; Creswell, 2009; Leedy & Omrod, 2005). In qualitative research, the researcher acts as the instrument of the study and derives meaning from the data (Gretchen & Sharon, 2003; Stake, 1995). This involves studying a phenomenon in its natural complex setting with due emphasis on various contextual factors which may influence the interpretations of events (Gretchen & Sharon, 2003), i.e., a real engineering classroom.

In particular, case study involves in-depth study of an individual, program or event for a defined period of time to build an in-depth understanding under the given context and underlying assumptions (Leedy & Omrod, 2005). A case study approach is beneficial when investigating about a poorly researched phenomenon. Particularly, they are useful when studying how changes in an individual or a program takes places over a period of time under the influence of circumstances or interventions. There is paucity of research about engineering instructors' in-class active learning implementation after attending a faculty development workshop. This lack of prior research guided the choice of case study approach as a research methodology for this study.

Case study approaches are limited when it comes to generalizability of the findings (Case & Light, 2011; Stake, 1995; Yin, 2003). However, the intent of case study is to examine multiple perspectives about the event under study (Yin, 2003). Case study approach places emphasis on interpretation where the researcher acts as an interpreter placed in the field to observe the functioning of the case, recorder who objectively records the details, and examiner of the events who derives meanings and justifies the constructed interpretations (Stake, 1995). The ability to gain rich contextual insights makes it an advisable approach to follow when studying "specific application of initiatives or innovations to improve or enhance learning or teaching" (Case & Light, 2011, p. 191). Faculty development workshops are one such initiative recommended to enhance student learning in engineering classrooms by promoting the use of active learning (PCAST, 2012). By conducting classroom observations, examining student and faculty perspectives using focus groups, surveys and interview, and justifying interpretations by triangulating findings from these multiple data sources, I examined two instructors' post-workshop use of active learning in an engineering classroom.

In summary, a case study approach is advisable when investigating how and why questions (Stake, 1995; Yin, 2003), developing new insights about a phenomenon or event (Leedy &

Omrod, 2005), studying application of initiatives (Case & Light, 2011) and studying a unique event which has been not been researched in the past (Case & Light, 2011; Yin, 2003). The type of research questions should guide the choice of research methods (Creswell, 2009; Krathwohl, 2009; McGrath, Martin, & Kulka, 1982). I used a case study approach because no prior work has been conducted to investigate the 'how' and 'why' questions about engineering instructors' post-workshop implementation of active learning in the classroom.

Preparing as a researcher

One the prerequisites for conducting efficient research is that the researcher should possess necessary skills to conduct the study. To develop these skills, it is recommend that the researcher should 1) work with multidisciplinary teams rather than being limited to single academic department, 2) analyze methodologies used in existing research and 3) participate in data collection prior to actual study to practice different techniques (Yin, 2003). In order to methodologically prepare myself as a researcher I followed the aforementioned steps. First, I worked for over a year with a multi-institutional research team comprising faculty members from education and core engineering departments, conveners of faculty development workshops and the head of an engineering faculty development research center. I was involved in development and validation of research tools (surveys, interview and observation protocols) as well as data collection (interview, observations and focus groups). Second, I reviewed existing case studies conducted in the field of engineering and STEM education (Iscioglu & Kale, 2010; Magin & Churches, 1995; Matusovich, Streveler, & Miller, 2010; Pamplona, Medinilla, & Flores, 2015; Stanley & Slattery, 2003). Third, I observed four courses offered by different engineering departments (electrical, chemical and mechanical) at two large research institutions. This experience allowed me to sharpen my skills to critically observe the events happening in a classroom and develop interpretations addressing contextual factors and rival explanations. An example of this work is presented in Shekhar and Borrego (in review).

Participants and Setting

The study was held at a large urban public research university located in US. The total undergraduate enrollment is 39,523 students for the year 2014. The college of engineering comprising eight departments offers bachelors, masters and doctoral degrees with 270 tenure track and 59 non-tenure track teaching faculty. The total undergraduate enrollment in the college of engineering is 5257 full time students. The course work requirement for a bachelor's degree ranges between 125 and 133 credit hours for the eight departments.

The case in this study is that of engineering instructors using active learning after attending a faculty development workshop. The National Effective Teaching Institute (NETI) is one such faculty development workshop conducted every year in conjunction with the American Society for Engineering Education's annual conference. From 1991 to 2005 , 1312 faculty members from 244 different institutions have participated in the workshop (ASEE, 2015). One of the key areas of focus of the workshop is to promote active learning. The instructors in this study were NETI attendees. Appendix E presents the table of contents for the NETI workshop.

To examine the case, the study design can be composed of single or multiple cases (Yin, 2003). There has been no prior work that has studied how workshop participation translates into in-class pedagogical practices of engineering instructors. Considering this lack of grounding research, I examined cases of two engineering instructors who were past NETI attendees in this study.

The first case study was conducted in an undergraduate upper division electrical engineering course. The instructor of the course attended the beginner level of the NETI workshop (NETI 1) in June 2011. At the time of observations, the instructor was close to attaining tenure in the department. He was nominated for outstanding teaching award in 2015. He had taught the course three times before the current offering. In addition to active learning, he used web based polls to get student feedback about the course and instruction. The class met two times a week for 75 minute sessions and had an enrollment of 65 students. The classroom featured an auditorium style seating arrangement. The space between the semicircular rows allowed the instructor to move around the classroom and monitor each individual student's work.

The second case study was conducted in an undergraduate upper division course offered by the department of civil, architectural and environmental engineering. The instructor of the course was a tenure track faculty member and recipient of award for outstanding engineering teaching by an Assistant Professor. The instructor attended both beginner (NETI 1) and advanced levels (NETI 2) of the NETI workshop. She had taught the course three times before the current offering. The total enrollment of the course was 21 students. The class was held twice a week with a 75 minute lecture and a 165 minute lab session. The lecture classroom featured a straight row seating arrangement with students seated in pairs and minimal space for the instructor to circulate around the room. On the other hand, lab sessions were held in a lab classroom where students were provided with computers and needed software tools. The space between the seats allowed the instructor to navigate around the classroom and monitor each individual student's work.

Data Sources

One of the main advantages of case study is the use of multiple data sources which help in addressing rival explanations, developing theoretical perspectives and establishing construct validity (Yin, 2003). The use of multiple data sources allows the researcher to triangulate the findings and to develop a convergent understanding of the event (Creswell, 2009; Leedy & Omrod, 2005). To conduct a robust case study, these multiple data sources should be used in a complementary manner (Yin, 2003). In alignment with these recommended practices for conducting case study, I used multiple data sources in my study as described in the next sections. Table 3.1 presents the data collection timeline.

Table 3.1: Data Collection Timeline

	Data Source	**Data Collection Timeline**
Case Study 1	Classroom Observation	Spring 2015 (15 Weeks)
	Student survey and focus groups	Spring 2015 (Final weeks of class)
	Instructor Interview	Spring 2015 (End of semester)
Case Study 2	Classroom Observation	Fall 2015 (15 Weeks)
	Student survey and focus groups	Fall 2015 (Final weeks of class)
	Instructor Interview	Fall 2015 (End of semester)

Classroom Observation

Observations are recommended for investigating events which have not been studied in the past as they allow the researcher to collect information about unforeseen scenarios (Leedy & Omrod, 2005). Lack of studies examining general and post-workshop use of active learning by engineering instructors guided the choice of conducting classroom observations in this study. Observations allow the researchers to gain insights about particular behaviors and environmental conditions relevant to the event under study (Stake, 1995; Yin, 2003). In addition, observations allow the researcher to collect data about events that the participants might overestimate in self-reports (Creswell, 2009; Ebert-May et al., 2011; Patton, 2002). For example, to study active learning implementation, Observations could be used "in the classrooms of seminar participants to determine whether these faculty members have incorporated this knowledge into their classroom performances." (Leydens, Moskal, & Pavelich, 2004, pp. 66-67).

Observations can be conducted in a casual, open-ended manner or can follow a structured protocol. An observational protocol serves as a "framework of behaviors that an observer is expected to record" (Leydens et al., 2004, pp. 67-68) and thus may ask the observer to collect evidence for occurrence of specific behaviors during a particular time frame (Yin, 2003).

In this study, I used the observation protocol developed by Shekhar et al. (2015) to study undergraduate engineering student resistance to active learning (Appendix A). The observations were conducted for every class session in the semester for the two case studies. The total observation time was approximately 110 hours for the study. I contributed as a member of the research team in the development and validation of the observation protocol. The development of the protocol was based on existing protocols such as RTOP (Sawada et al., 2002), UTOP (Walkington et al., 2011), OTOP (Wainwright, Flick, & Morrell, 2003), TDOP (Hora & Ferrare, 2013), and COPUS (Smith, Jones, Gilbert, & Wieman, 2013). The protocol focuses on documenting different types of student resistance with respect to the type of active learning and other contextual factors. The key elements of the protocol are described below:

- *Type of material:* This section documents the details of the material covered for a particular class session. The protocol asks the observer to report newness (new/review) and the difficulty level (difficult/easy) of the material. The observer was also required to document the basis for selecting among the two options.
- *Type of active learning*: For each instance of active learning, the protocol asks the observer to choose from the listed types of commonly used active learning (think–pair-share, group discussion and group problem solving). In addition, the protocol provides open ended space for the observer to document other types of active learning that were not present in the list.
- *The degree of instructor participation:* For each instance of active learning, the protocol asks the observer to document the approximate degree of instructor participation. The degree of engagement was categorized into high (when the instructor circulates around the classroom and monitors student progress), medium (when the instructor only answers students' questions without intervening in their work or monitoring their progress) and low (when there is no interaction between the students and the instructor).
- *The degree of student engagement:* The protocol asks the observer to identify engagement levels based on approximate percentage of students engaged during activity as high (more

than 90 % students engaged), medium (50%-90% engaged) or low (less than 50% engaged) for each instance of active learning.

- *Type of student resistance:* This section is focuses on documenting specific details about the ways in which students resist during an active learning exercise. The protocol asks the observer to identify the type of demonstrated resistance based and report approximate percentages of students demonstrating each type. The listed types of student resistance are partial compliance; passive, non-verbal resistance; and open resistance, derived from Weimer (2013).

In addition to the main protocol that was completed for every instance of active learning, I used the additional form designed to be filled on first day of class to document details about the class such as class size, seating arrangement, grading policy and classroom expectations. Furthermore, consistent with good practice for collecting observational data (Leydens et al., 2004), I used the open ended comment sections of the protocol to record additional contextual details and my in-field reflections about the occurring events.

Instructor Interview

The purpose of case study is to obtain description of the occurring events and interpretation of other stakeholders (Stake, 1995). Interviews are an important data source in case study research as they allow the researcher to obtain multiple perspectives (Stake, 1995) and answer the "why" questions regarding the event under study (Yin, 2003). Interviews allow capturing unobservable data such as participants' thoughts and perspectives and assist in validating and complementing observational findings (Leydens et al., 2004). In this study, I interviewed the instructor to validate the classroom observation findings and investigate the reasoning behind the selection and implementation of active learning exercises in the classroom.

For case study research, it is recommended to conduct semi-structured interviews as a guided conversations with focus on both the planned line of inquiry and subsequent questions to corroborate or contrast the findings from other data sources (Yin, 2003). Such a conversational format provides the researcher with “maximum flexibility to pursue information in whatever direction appears to be appropriate, depending on what emerges from observing a particular setting” (Patton, 2002, p. 342).

I used a semi structured interview format in my study by starting with a set of predetermined questions asking the instructor about his/her conceptions about the implemented active learning, prior teaching experiences, implementation challenges and student reactions, followed by questions probing to validate and refine the observational data. The interview was conducted at the end of semester and lasted for approximately an hour. During the interview, the instructor was presented with preliminary findings. Consistent with good practice for conducting research, the interview was audiotaped for future reference and analysis. The general line of questioning included:

1) How do you describe active learning?
2) As an instructor, what do you think is the purpose and benefit of active learning?
3) How long have you been doing active learning? Have you made any changes in the active learning format since then?

4) Have you faced any problems or challenges in implementing active learning?
5) How do you design an active learning exercise – in term of questions, frequency of occurrence in a semester?
6) Additional follow up questions based on observations, focus groups and survey data. (Appendix B).

Student Survey

A survey has been recommended in a case study as an additional data source to cater to some part of the overall inquiry (Yin, 2003). In this study, I used a survey instrument to study students' response to active learning (Appendix C). The survey provided more generalizable findings within each case due to higher number of participants. The survey was administered at the end of semester. A response rate of 87% and 86% was achieved for the first and second case study respectively. The purpose of the survey was twofold. First, the survey was used to gather students' response to active learning used in the course. The survey asked the students to report their response to active learning (student resistance, behavioral and emotional response) on 5 point Likert scale (Almost never, Seldom, Sometimes, Often and Very Often). Second, it aimed to examine whether the students wanted more or less of the different types of active learning exercises that were implemented in the course. The survey asked the students to indicate whether they would want more or less of the listed activities in their ideal course class on a 5 point Likert scale (Much Less, Slightly Less, About the same, Slightly more, Much more).

Student focus groups

Focus group is a type of interview that involves a small group of participants with similar backgrounds (Creswell, 2009). The discussion style format facilitates interaction among the participants yielding high quality data. Specifically, focus groups allow gathering multiple perspectives, comments about others' opinions and identifying consensus or shared views about the topic under consideration (Patton, 2002).

In case study research, it is recommended that the researcher should "go beyond simple repetition of data gathering to deliberative effort to find validity of data observed" (Stake, 1995, p. 109). In this study, student focus groups were used to validate the findings of classroom observations and gain students' opinions about the implemented active learning in the classroom. A total of 8 students in the first case study and 21 students voluntarily participated in 4 separate focus group sessions at the end of the semester. The questions included:

1) What are your thoughts and opinions about the active learning exercises the instructor did during the lecture? Did your peers in the class share the same view?
2) Did most of the students fully participate in the activities? If not, what did they do during the activity time?
3) Would you like more lecturing or active learning?
4) What in your opinion should the instructor have done better to improve the teaching?
5) Additional questions based on observations (Appendix D).

Data Analysis

One of the strengths of a case study approach is its ability to monitor changes over time (Yin, 2003). A chronological time series analysis allows studying multiple variables, identifying trends and providing richer insightful descriptions (Yin, 2003). In this study, the classroom observations were analyzed chronologically to understand the implementation of active learning over the course of a semester. For chronological analysis, it recommended to “identify the specific indicator(s) to be traced over time, as well as the specific time intervals to be covered” (Yin, 2003, p. 127). The observation protocol was used to document levels of indicators (e.g. student resistance, instructor participation) for every instance of the various types of active learning used during the semester.

The analysis of case study data is conducted simultaneously during the data collection process, which informs the data collection for the later phases of the study (Leedy & Omrod, 2005). The initial findings and perspectives can either support or contradict existing theory. The researcher uses both supporting and contradicting explanations to build a descriptive understanding of the phenomenon during the inquiry process (Yin, 2003). In this study, observational data was used to refine student focus group questions. Specifically, the observations findings and initial interpretations were triangulated using student focus groups. The synthesized data from classroom observations, student surveys and focus groups was used to inform the instructor interview process.

An important goal of case study is “to examine some relevant ‘how’ and ‘why’ questions about the relationship of events over time, not merely to observe time trends alone” (Yin, 2003, p. 127). An analysis involving explanation building is recommended for case study approach. Explanation building is best described as “the process of refining a set of ideas, in which an important aspect is again to entertain other plausible or rival explanations” (Yin, 2003, p. 122). This process of explanation building occurs in narrative form in which “ the explanations have reflected some theoretically significant propositions” (Yin, 2003, p. 120). In this study, the observational data presented in a narrative form provided a chronological account of active learning implementation and other data sources (interview, focus groups and survey) were used to build “how” and “why” explanations examining the influence of instructor conceptions and student factors (student resistance and expectations) on the use of active learning in the classroom.

The analysis of case study data involves organization of detailed information about the case, categorization of data, interpretation of single instances, identification of patterns, and lastly synthesis and analytical generalization of findings for the given case (Leedy & Omrod, 2005). The primary task in this process is to build an understanding of the case. The case is usually complex with multiple factors influencing the occurring events, and focusing on “formal aggregation of categorical data is likely to distract attention to its various involvements, its various contexts ” (Stake, 1995, p. 77). Two recommended strategies for analysis of cases study data are direct interpretation of the individual instance and aggregation of multiple instance to answer holistic questions about the case (Stake, 1995). A case study researcher “concentrates on the instance, trying to pull it apart and put it back together again more meaningfully – analysis and synthesis in direct interpretation" (Stake, 1995, p. 75). In this study, the classroom observation protocol filled for every instance of active learning provided detailed information about the occurring event in terms of student and instructor engagement patterns. While the surveys were used to inform analytical generalizations made towards the investigated case, the focus groups helped in gaining a detailed interpretation about the active learning exercises from a students' perspective. Lastly, the instructor interviews were used to understand instructor's perceptions about the various documented events (active learning instances), the categorized properties (student resistance and classroom expectations) and theorized interpretations (influence of conceptions and classroom factors on post-workshop active learning implementation).

Quality in Qualitative Research

In qualitative research, trustworthiness of findings is established by triangulating results from multiple data sources, gathering feedback from the participants about the collected data and emergent findings and providing detailed descriptions of the setting (Creswell, 2009). In this study, I followed the recommendations to enhance the trustworthiness of the results. First, I used findings from multiple data sources (classroom observations, instructor interviews, student focus groups and surveys) to support claims and assertions. Second, I gathered feedback on the observational findings from the students during the focus groups. The student response section of the next two chapters present the observational findings and follow-up student feedback for the two case studies. Third, I provided detailed description of the settings for the two case studies examined in this study. In addition to institution and participants' details presented in this chapter, the background section of the two case studies provide details of the contextual factors relevant to the study including but not limited to classroom layout, in-class announcements (e.g. benefits of active learning), additional course components (e.g. feedback polls and videos) and techniques (e.g. assigning student teams) used by the instructors.

Although case study approaches are limited when it comes to generalizability of the findings (Leedy & Omrod, 2005), researchers have argued that the results can be generalized by converging findings between cases (Creswell, 2009). In the conclusion and discussion chapter, I present a comparison of the results between the two case studies and the emergent results in the context of existing literature to enhance the generalizability of the findings.

IV. Chapter Four: Case Study 1

Overview

This case study was conducted in an undergraduate upper division course offered by the department of electrical engineering. The course instructor attended the beginner level of NETI workshop in June 2011. He had taught the course three times prior to this offering. The instructor used two types of active learning in which he engaged the students in group discussions and problem solving exercises. Group discussion based activities were primarily used in the semester in which the instructor asked the students to discuss the answer to the posed question in groups. The problem solving exercise asked the students to work on the posed problem during class time. In following section, I first provide a background about the course under study. In the subsequent sections, I present students' and instructors' responses to the two types of active learning used in the semester. Lastly, I summarize the findings of the chapter.

Background

The classroom featured an auditorium style seating arrangement. The space between the semicircular rows allowed the instructor to move around the classroom and monitor students' work. The seats were attached to movable base and allowed students to turn around to talk to each other during group work. Besides active learning, the instructor incorporated additional noteworthy components to aid classroom instruction. First, the instructor talked about how the content will be useful in the industry as an electrical engineer. Second, the instructor presented open source videos about various covered topics during the lecture. These videos were predominantly used in the first quarter of the semester. Third, the instructor used web-based polls to get student feedback about the course and his instruction. A small percentage of final course grade was assigned to these polls to encourage participation.

During the semester, the instructor used two types of active learning in which he engaged the students in group discussions and problem solving exercises. For almost every active learning instance, the instructor demonstrated high level of participation where he circulated around the classroom during the activity encouraging students to engage in the discussion. The participation in the activities did not count towards final course grade. The instructor announced that he will be doing active learning for which he has received good feedback in the past semesters and he expects the students to participate on the first day of class. Typically, each active learning session lasted for less than 5 minutes.

Except one problem solving exercise, the instructor primarily used group discussion-based activities in the semester. Furthermore, most of the group discussion activities implemented in the semester involved a broad question. I observed variations in student responses depending on the type of activity (discussions and problem solving exercises).The following sections describe student and instructor response to group discussions and problem solving exercises.

Group Discussions

Discussion activities followed the format of 'think-pair-share' which asks students to discuss the answer to a specific question in groups. At the end of an activity, the instructor called upon almost every group to report their answers. While calling upon groups, the instructor asked for a representative of the group. Since the students usually occupied the same seats, their groups were comprised of the same set of students for a majority of the class sessions. In most of the active learning instances, the same student representative summarized the results of the discussions to the whole class.

In addition, the instructor cross-questioned the students' responses at the end of the activity. This generated new questions which were posed to the whole class to answer. In most of the cases, only a small percentage of students who were usually engaged in the class responded to these additional questions. In a majority of the cases, the instructor left these additional discussions open-ended without providing a concrete answer.

Student response to group discussions

In the focus groups, students gave overall positive feedback about these discussions. However, they expressed concerns about implementation. One student responded, "I did like them. I felt certain questions were a lot better for discussion than others". Another student echoed:

> I like the idea of group collaboration. It stimulates thought. It forces people to put their mind on their material. But, I feel maybe like they were implemented somewhat poorly because, like, so often the exercise was done on a general broad topic but the lesson dives deep in. So, the usefulness of the group activity was lost. It was like, we talked about it, but why?

Variations in student engagement were observed based on the type of questions posed during the discussion. Group discussions in which the questions were not too broad and their complexity was within students' current understanding of the content received an overall high participation of over 90% of students. In the focus groups, the students gave positive feedback for discussion with questions that were appropriately complex to students' current content knowledge. As one student mentioned, "I remember one of the first questions he asked was what electricity is. That's like a freshman-level question but it's interesting, the misconception that the people have even at this late stage in their education". Although a few students demonstrated passive resistance in which they did not join a group at the beginning of the activity, the instructor was able to mitigate this by approaching these students and asking whether they are part of a group or not.

On the other hand, group discussion activities involving broad questions received lower engagement with more than 50% of the students disengaged from the activities. Students primarily demonstrated partial compliance by completing the activity very quickly with minimal discussion, after which students sat idle or engaged in off-task discussions for the remaining time. Focus group responses confirmed the occurrence of short discussions and highlighted the broadness of the questions as the primary cause. One of the students explained, "I think it definitely depended on the question that was asked." Another student expressed that "we usually discuss for like 10-20 seconds and then you kind of sit there a little bit and wait till he brings the class back together. Obviously, if the question is more relevant, we could answer it". In other words, due to the irrelevancy and complexity of the posed questions, students were not able to participate meaningfully in the discussion. Consequently, they demonstrated resistance during such activities by giving minimal effort to the activity and engaging in off task discussions.

In the survey, a majority of the students reported that they demonstrated partial compliance and passive resistance 50% or more of the time. Specifically, 72% of students reported that they focused on doing what the instructor asked, rather than on mastering concepts, and 63% reported that they rushed through the activity giving minimal effort. In addition, 63% students reported that they demonstrated passive resistance by talking with classmates about other topics besides the activity (Table 4.1).

In response to broad questions, students typically guessed or gave vague answers for most of the discussions. In the focus group session, one student explained, “Some of the ones on basic concepts were actually good… and then you know we did not really know what we were doing so we kinda come up with half-assed answers”. Another student echoed, “And I think the whole point of a discussion is you have to be able to argue reasoned positions, so if we don’t have enough knowledge, we just end up guessing”. Students’ inability to come up with concrete answers was also evident in one of the student’s in-class responses. In one such instance, a student prefaced his group’s report with “I don’t know if this is a good enough of an answer…”.

Table. 4.1: Student Resistance to Active Learning (n=57)

How often did you react in the following ways?	Almost never (< 10% of the time)	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very Often (> 10% of the time)
I focused on doing specifically what the instructor asked, rather than on mastering the concepts.	9%	19%	30%	25%	17%
I rushed through the activity, giving minimal effort.	16%	21%	30%	19%	14%
I talked with classmates about other topics besides the activity.	12%	25%	26%	25%	12%
I surfed the internet, checked social media, or did something else instead of doing the activity.	33%	14%	23%	21%	9%
I pretended but did not actually participate.	33%	23%	19%	14%	11%
I distracted my peers during the activity.	58%	19%	7%	12%	4%
I disliked the activity and voiced my objections.	72%	7%	11%	7%	3%
I participated actively (or attempted to).	3%	9%	28%	44%	16%
I tried my hardest to do a good job.	0%	3%	26%	46%	25%

In addition to partial compliance, in multiple instances students also demonstrated passive resistance by refusing to join a group. During the activity, the instructor approached these students and insisted they move closer to each other and start a discussion. Upon instructor's insistence, these students moved closer to each other and started the discussion. However, the discussions lasted for a short duration and the students reverted to off-task activities. Thus, the instructor’s intervention was not able completely mitigate student resistance. Similar to other discussions with broad questions, the students now demonstrated resistance in the form of partial compliance. In other words, instructor’s intervention was only marginally successful and typically resulted in the brief discussions followed by off-task work characteristic of partial compliance.

Finally, I also observed that student attendance declined after the first exam and remained low with nearly half of students absent for most of the semester. In addition, I observed one instance in which a few of the students who were usually absent left the classroom immediately after the instructor introduced a discussion exercise. When asked about the reasons behind the decline in attendance, students reported that the primary cause was that most of the students received high grades on the first exam. Students also attributed it partly to the classroom discussions. A majority of the students felt that the discussions did not contribute to helping them learn the material: “Yeah, I guess people feel like the class isn’t adding anything, especially the discussions”. Another student echoed, “Personally, I did not think it helped with homework or exams so much but it did help give you a general background of microelectronics”. One student attributed it more specifically to the disconnect between active learning exercises and exam questions, mentioning, “It was more of the open-ended questions and it didn’t formulate on the test. You probably lost lot of people after the first test because of that”.

Thus, although students provided positive feedback about discussion-based activities, they expressed concerns about choice of questions posed during discussions. The classroom observation data indicated variation in student engagement based on the type of posed questions.

Specifically, discussions with broad questions received lower engagement when compared to discussions in which the questions were not too broad and their complexity was within students' current level of understanding. Student resistance took the form of passive resistance and partial compliance. Overall, due to their broadness and disconnect of discussions with homework and exam questions, discussion based activities received low engagement throughout the semester. The student survey results indicated that although students felt positively towards the instructor, more than half of the students did not enjoy the activity and felt the effort and time used in the activity was not beneficial (Table 4.2). For example, 58% of students did not find that the effort it took to do the activity was worthwhile for 50% or less of the time. Similarly, 54% students did not find that the time used for the activity was beneficial for 50% or less of the time.

Table 4.2: Student Emotional and Value Response to Active Learning (n=57)

How often did you react in the following ways?	**Almost never (< 10% of the time)**	**Seldom (~30% of the time)**	**Sometimes (~50% of the time)**	**Often (~70% of the time)**	**Very Often (> 10% of the time)**
I felt the effort it took to do the activity was worthwhile.	14%	18%	26%	35%	7%
I felt the time used for the activity was beneficial.	12%	12%	30%	26%	20%
I saw the value in the activity.	9%	12%	28%	26%	25%
I enjoyed the activity.	7%	7%	40%	28%	18%
I felt positively towards the instructor/class.	0%	5%	32%	37%	26%
I felt the instructor had my best interests in mind.	0%	7%	23%	32%	38%

Instructor response to group discussions

The instructor interview response emphasized interaction and student engagement as the primary advantages of active learning. In addition, the instructor mentioned that active learning allows students to "contemplate the questions and topics being presented" and serves as an "avenue for them (students) to have real time contemplation and narrative discussion". The instructor reported that he has been using similar activities since attending a faculty workshop and felt confident based on pervious course evaluations. The influence of faculty conceptions about active learning was evident in the design of discussion questions. Expressing the challenge he faced in designing the questions, the instructor explained:

> This is an engineering class, it is not like political, you know, literature class where there is a wealth of questions one could discuss. In a very technical class like this it's often right or wrong answers. That's really not the spirit of active learning. So, I had to really think very deep and really go to kind of a more abstract level of exactly what is this material is about the subject matter and not dwell too much on these very very specific narrow issues. So by going to this more elevated abstract plane, then I can generate questions that have guided the development of the field that is still relevant today.

He believed that active learning is not associated with problems which have right or wrong answers and designed abstract questions which in his view would best facilitate discussion and engagement. This was evident in his statement: "They are still very practical questions, but maybe questions that are not necessarily discussed in classrooms but you hear about them in popular media…it gives [students] a platform to voice their opinions and discussion amongst themselves”.

In response to survey results in which the students reported that they often partially complied during the activity (Table 4.1), the instructor initially identified group dynamics and classroom layout as probable reasons for student disengagement. Upon discussion of focus group results identifying overly broad questions as a reason, the instructor acknowledged their broad nature and reiterated the challenge he faced in designing suitable questions. The expectation of guessing was also evident in the instructions he gave in class, including to “identify plausible reasons or guess” the answer to the question.

Thus, contrary to focus groups findings, in which students expressed concerns about the abstract nature of posed questions, the instructor believed that it was in line with the intent of active learning and the abstractness facilitated discussion and promoted engagement. The choice of questions emerged as the primary reason behind student resistance. In other words, the mismatch between the design of activities with students’ preferred level of complexity and irrelevancy to course components important to students such as homework and exams contributed to low student engagement in the classroom.

Problem Solving Exercises

During the final week of the semester, instead of a discussion question, the instructor posed a problem to the entire class to solve. This problem solving task required basic calculation and application of prior electrical circuit knowledge that undergraduate students would be familiar with. In other words, the problem solving task was relevant to other course components and appropriately complex with respect to students' current level of understanding.

This single instance is presented separately to highlight two key findings. First, despite minimal encouragement from the instructor, this activity received high student engagement due to the clear relevance to homework and exam content. Most of the students worked on the problem for the entire allotted time, and students volunteered to present their answers to the instructor by raising their hands as opposed to waiting for the instructor to call on discussion groups in turn. Second, the instructor attributed this activity to his prior teaching experience and not the workshop. Unlike the discussion exercises which included details about allocated time and instructions to form a group, this problem was not presented as a formal active learning exercise. Nonetheless, students were highly engaged. In the following sections, I describe student and instructor response to the problem solving exercise and also present comparisons with discussion-based activities.

Student response to problem solving exercise

In spite of not being formally introduced as an active learning exercise, students demonstrated high levels of engagement with almost whole class engaged in the activity. In contrast to the discussion-based activity where students engaged for a small portion of the allocated time, most of the students worked on the assigned problem for the entire period of time. Also, in comparison with discussions in which the instructor called upon students at the end of the activity, students volunteered to present their answers to the instructor by raising their hands at the end of the exercise.

Focus group responses highlighted the choice of posed question as reason for high engagement in the problem solving exercise. For discussion questions, students expressed their concerns about the broadness of the question in regard with their current understanding of the content and the inability of discussion to help in solving homework or exam problems. On the contrary, student focus group response indicated that the problem solving exercise received high participation because they were not broad as compared to discussion and was more relevant with respect to homework or exam problems. Comparing problem solving activity with discussions, one student expressed: "Whereas a lot of the other questions where kind of like – what you thought about this. But, there was not really a problem per se". Another student stated, "Those are pretty much open ended questions that he asked during the group activity … when he did the resistors example that was basically going along with circuits but [sic] what we were doing in our homework.".

In the student survey, approximately half of the students indicated that they would prefer more problem solving in their ideal course. 53% of the students indicated that they would prefer more group problem solving, while only 3.5% students indicated they wanted less. Similarly, 47% of students wanted to do more individual problem solving in class but just 10% wanted less. Students also expressed their concerns regarding the lack of computational problems in the lecture in the student feedback polls conducted by the instructor.

Table 4.3 reports Pearson correlations between survey items, which demonstrate that students who wanted more problem solving self-reported greater resistance to the discussion activities throughout the semester. Students who wanted more group problem solving indicated that they focused on doing specifically what the instructor asked in discussion, rather than on mastering the concepts (r = .332). Similarly, students wanting more individual problem solving reported that they rushed through the discussion activity giving minimal effort. In addition, students with group problem solving preferences indicated that they pretended but did not participate in the discussion exercises (r = .277). Two items about the value of the discussion activities were negatively correlated with students wanting more problem-solving. Specifically, students who disagreed the effort for discussion as worthwhile wanted more individual problem-solving (r = -0.314), and students who felt that the time used for discussion was not beneficial wanted more individual (r = -.279) and group (r = -.275) problem solving in their ideal course.

Table 4.3: Instructional Preference (n=57)

	Solve problems in a group during class	**Solve problems individually during class**
I focused on doing specifically what the instructor asked, rather than on mastering the concepts	0.332*	0.091
I rushed through the activity, giving minimal effort	0.189	0.299*
I pretended but did not actually participate	0.277*	0.253
I felt the effort it took to do the activity was worthwhile	-0.194	-0.314*
I felt the time used for the activity was beneficial	-0.275*	-.0279*

*Correlation is significant at the 0.05 level (2-tailed).

Instructor Response to problem solving exercise

Instructor interview response suggested that the instructor was in favor of problem-solving activities but struggled with designing suitable problems. He explained, "In principle that will be very good to do. But this kind of very higher-level senior classes, I have to think about problems that are suitable within the boundaries of time in a group of 2 or 3 people". He also mentioned that student feedback requesting more problem-solving is recurrent. He described this advanced undergraduate course as "very analytical" and that "The nature of analytical classes wants you to do more problems … Then, [instructors must consider] how to integrate actual analytical problems and concepts in active learning, I am not sure how one can do that successfully". He recommended that workshop facilitators should provide support in developing content-specific active learning questions, stating:

> You have to keep in mind that [NETI] workshop is across all the engineering. So, it's only a subset of similar engineering faculty will be present. So, at least what they have used in the past is kind of generic things that are not content specific. But maybe if they had a handbook in which they said "for this kind of engineering and that kind of engineering classes, this is some examples that have been very successful example questions.

Initially, the instructor did not identify the problem as active learning. He commented, "I did not decide [that problem-solving activity] as active learning. I have done that problem in class previously, and I felt the students really took great interest in this. It is something that they would need to use actually in their homework and exams". By the end of the interview, he recognized it as an example of the type of problems that he needs to increase for in-class activities.

Summary

In summary, the selection and design of active learning exercises was influenced by instructor‘s conceptions about active learning. The instructor’s conception that active learning solely aims at increasing classroom interaction and questions with right or wrong answers are not in line with active learning led to the selection of discussion-based activities. Due its complexity and irrelevance to homework or exam problems, discussion questions were reported by students as the primary causes behind their disengagement in the active learning exercises.

Variations in student engagement were observed based on the type and design of active learning. Table 4.4 summarizes the variations in student engagement based on the type and design of active learning in this case study. While discussions without broad questions received passive resistance, instructor intervention was able to mitigate it, which lead to overall high engagement. For discussion-based activities with broad questions, instructor intervention was able to reduce passive resistance but student partially complied leading to low engagement levels. On the contrary, the problem solving exercise received high engagement since the students were able to effectively work on the posed problem and it was relevant to homework or exams. Thus, the inability of activities to translate into homework or exam problems and the broadness of posed questions emerged as the primary reason behind student resistance.

Furthermore, the instructor reported that he struggled in designing active learning exercises after attending NETI 1 workshop and suggested the inclusion of more support and training in developing content specific questions for active learning in the workshop. In addition, he expressed concerns regarding the lack of interaction opportunities with other faculty members teaching similar engineering courses.

Table 4.4: Variations in student engagement

Type of Active Learning	**Type of questions**	**Student Engagement**	**Student Resistance**	**Instructor Intervention**
Discussion	Broad and irrelevant to homework or exams	Low	Passive and partial compliance	Mitigates passive resistance but not partial compliance
Discussion	Not broad but irrelevant to homework or exams	High	Passive resistance	Mitigates passive resistance
Problem solving	Not broad and relevant to homework or exams	High	None	No resistance even though minimal intervention

V. Chapter Five: Case Study 2

Overview

This case study was conducted in an undergraduate upper division course offered by the Department of Civil, Architectural and Environmental Engineering. The undergraduate students were either at junior-level or senior-level. The course content covered various topics associated with building modelling such as construction planning, design and operation. The course instructor attended both beginner (NETI 1) and advanced levels (NETI 2) of the same faculty development workshop as the instructor in first case study. She had taught the course three times prior to current offering. In this chapter, I first provide a background about the course under study. In the subsequent sections, I present students' and instructors' responses to the overall use of active learning and responses to the different types of active learning used in the semester. Lastly, I summarize the findings of the chapter. Table 5.1 provides an overview of the sections presented in this chapter.

Table 5.1: Overview of the chapter

Chapter Section	Description
Background	• Description of the course. • Active learning instruction. • Relevant classroom practices followed by the instructor.
Overall Response to Active Learning	• Students' in-class behavior, focus group and survey response to active learning. • Instructor's thought process behind the design and use of active learning. • Instructor's workshop experience.
Response to various active learning types	• Students' in-class behavior, focus group and survey response specific to the different types of active learning. • Follow-up instructor's interview responses.
Summary	• Summarizes the findings of the chapter.

Background

On the first day of class, the instructor discussed the benefits of the course which were primarily industry specific such as teamwork, real world projects and presentations. In addition, the instructor conducted a survey asking students about their background knowledge and content-related experience. The survey responses were used by the instructor for assigning students to different groups. The students were required to work with their assigned group members on multiple projects assigned during the semester. The instructor explained to the students that how in the real world engineers do not get the opportunity to choose their teams and are assigned based on their expertise and skill set.

The course was divided into four cycles catering to construction engineering topics: Model-based Cost Estimating, Project Scheduling and 4D Simulation, Design Coordination and Construction Progress Monitoring. Each cycle included a lecture session, hands-on lab, question and answer lab, and a presentation session. In the lecture session, the instructor taught the content related to the specific topic and provided industry specific examples and used online videos. In addition, the lecture session included active learning exercises in which the instructor engaged students in group discussions. The lecture session was followed by two lab sessions. In the hands-on lab session, the students were taught the material using software demonstrations by the instructor and her teaching assistant. In the question and answer lab session, they worked on their assigned group projects under the guidance of the instructor and the teaching assistant. Lastly, the students reported their project results through group presentations. Participation in the activities counted towards 10% of the final course grade. In the next sections, I first present student and instructor response about the course and its active learning-based instruction. In the subsequent sections, I present student and instructor response to the various active learning types implemented in the semester. Table 5.2 presents the different types of active learning implemented in the course.

Table 5.2: Type of Active Learning used in the semester

Type of Active Learning	Description
Hands-On Lab Session	Student follow demonstrations to familiarize with different software tools needed for the project.
Question and Answer Lab Session	Students work on their projects in groups under the instructor's guidance.
Group Discussions	Students discuss assigned readings and other course topics.
Student Presentations	Students give group presentations for their projects and case studies.

Overall Response to Active Learning

Student Response

Student In-Class Engagement

Overall, the observed levels of student engagement remained high throughout the semester for the active learning exercises. The majority of the students actively participated in the activities and demonstrated resistance remained significantly low during the semester. Student survey reports confirmed high engagement in the activities. A response rate of 86% was received for the student survey. In the survey, 94% students reported that they actively participated in the activities for 70 % or more of the time. Similarly, 88% students reported that they tried their hardest to do a good job during the activities for 70% or more of the time. In addition, a majority of the students indicated that they demonstrated resistance for 30% or less of the time. For example, 83% students reported that they distracted their peers during the activity for 30% or less of the time. Similarly, 88% students reported that they did something else instead of doing the activity for 30% or less of the time. Table 5.3 presents students' in-class response to active learning reported in the survey.

Table 5.3: Student In-Class Response to Active Learning (n=18)

How often did you react in the following ways?	Almost never (< 10% of the time)	Seldom (~30% of the time)	Sometimes (~50% of the time)	Often (~70% of the time)	Very Often (> 90% of the time)
I distracted my peers during the activity.	61%	22%	11%	6%	0%
I rushed through the activity, giving minimal effort.	32%	38%	30%	0%	0%
I surfed the internet, checked social media, or did something else instead of doing the activity.	56%	32%	6%	6%	0%
I focused on doing specifically what the instructor asked, rather than on mastering the concepts.	6%	16%	50%	28%	0%
I disliked the activity and voiced my objections.	94%	6%	0%	0%	0%
I pretended but did not actually participate.	62%	32%	6%	0%	0%
I talked with classmates about other topics besides the activity.	6%	44%	22%	17%	11%
I participated actively (or attempted to).	0%	0%	6%	67%	27%
I tried my hardest to do a good job.	0%	6%	6%	44%	44%

Student Emotional and Value Response

In almost every focus group session, students provided positive feedback about the use of active learning and recognized its value. Students reported that they enjoyed engaging in the active learning exercises, as evident in this student comment,

> This was one of the best classes I have taken here at [Institution]. It's just really nice to work with other people and like be able to throw ideas off each other. Rather than just go to a lecture and sit there and like have something explained to you and they go on for an hour and you don't do anything.

In addition, students reported that the active learning methods were beneficial to their learning and helped them in understanding the course content. For example, when asked about the influence of the participation grade on high engagement, one student responded,

> I don't actually think about the participation grade at all. To me it's like this is actually a class that I am interested in and when I am engaged, I am seriously engaged for wanting to know more for my benefit. That's not typically the case for some of my other classes, specially the more technical structural ones, but at least for this one, I completely forgot that there is a participation grade.

Similar to student focus group responses, student survey results indicated that most of the students felt positively about the activities and saw the value of active learning (Table 5.4). For example, 94% students felt positively towards the instructor/class for 70% or more of the time.

Similarly, 100% of the students reported that they saw the value in the activity for 70% or more of the time.

Table 5.4: Student Emotional and Value Response to Active Learning (n=18)

How often did you react in the following ways?	**Almost never (< 10% of the time)**	**Seldom (~30% of the time)**	**Sometimes (~50% of the time)**	**Often (~70% of the time)**	**Very Often (> 90% of the time)**
I felt positively towards the instructor/class.	0%	0%	6%	22%	72%
I felt the instructor had my best interests in mind.	6%	0%	6%	22%	66%
I enjoyed the activity.	0%	0%	6%	55%	39%
I felt the effort it took to do the activity was worthwhile.	0%	6%	11%	44%	39%
I saw the value in the activity.	0%	0%	0%	39%	61%
I felt the time used for the activity was beneficial.	0%	0%	11%	39%	50%

Reasons Behind Engagement

While survey findings provided support to observed student engagement, student focus group responses provided additional insights about the reasons behind high student engagement. The focus group findings highlighted four main reasons behind students' positive response to active learning. First, students expressed satisfaction with the applicability of various course components to real-life scenarios, as summarized in this student comment,

> I personally like how we have to, it's a combination of working with a software most of the time and coming up with quantitative and qualitative data. And actually writing your report complements that. I think you get the best of both things – working on a computer

> and analyzing it as opposed to just submitting a soft copy. And everyone gets a chance to present that. You do it on a computer, you write it down, you present it and then you communicate to other people. It's very much how you do it in an actual job. That's what I like about it.

Another student noted, "She has really put thought into it. The way she organizes the course is very interesting. Everything is sequential. The ideas, the concepts that are presented are in sequence of how they actually might occur in real life".

Second, students provided positive feedback for the design of active learning exercises in terms of relevancy. In most of the focus group sessions, students reported that they engaged in the activity because the activities were relevant to assigned homework problems and applicable to the field of study. For example, contrasting with other undergraduate active learning courses, one student commented,

> Like for example, I have another class and we do similar things. It's like she lectures and then breaks off into groups to do little like projects or little activities and nobody participates … it's because it's like things that people don't find applicable. Unlike my other class, I feel like, here in this class, everybody finds [it] applicable, as we are going into that field.

Pointing out specifically the relevancy of the exercises with homework problems, a student experiencing active learning for the first time, expressed: “It’s a different class. I mean, for me, it’s something very different that I never saw, like ever. I just like, that’s why we like to participate, do the homeworks in the lab sessions”.

Third, in the focus group responses, students consistently reported satisfaction with the level of complexity of the active learning exercises. Students expressed that the activities were appropriately designed for them to engage in the class without being overburdened. For example, a student mentioned,

> I think the way she structured it. She has put a lot of thought into it. And the outcome is that we are able to cover a lot of material pretty in depth and at a high quality level … So, rather than dropping something here and there, you really learn all the content. She is able to keep everyone working at the high level, covering a lot material, and it’s not totally overwhelming.

Fourth, students reported the use of a variety of active learning types as a reason behind high engagement, as evident in this student remark, “If every class would be like this. I would want that. Because it’s not lecture every class, she switches it up between lab, lecture, case study, discussion and presentations. It’s like there is something new every time”.

Another student echoed,

> I think it's nice that she kind of incorporates various ways of teaching things. So, she has the lab, she has the lectures, she goes over the slides, and then she also has the teaching assistant to go through and teach us again, and walk us through how we apply those things we are learning. It kind of helps people learn things in various different ways.

To summarize, student classroom engagement remained high for a majority of the course. Student survey results indicated that the majority of the students valued the activities and felt that they were beneficial to their learning. Student focus group responses noted applicability of the course components, relevancy and appropriate complexity of active learning exercises, and use of a variety of active learning techniques as reasons behind high engagement. In other words, due to the effective design of the active learning exercises in terms of relevancy and complexity, students positively responded to active learning during the semester. As described in the next section, the instructor response demonstrated consistency with student feedback and further elaborated the aspects of active learning design that help in promoting student engagement.

Instructor Response

During the interview, the instructor reported that she attended the NETI 1 and the NETI Advanced (NETI 2) workshop in June 2011 and October 2011 respectively. When asked to describe active learning, the instructor noted the importance of learning through engagement in classroom exercises, as evident in this remark:

> I like to describe it as the information goes from the instructor, the board or the wherever I am displaying the information or the knowledge, to the students' notes but going

> through their brains. I like to describe it as, it's engaging, it's something that they literally have to apply it to their own mental models in class. Not just outside of class but class time is thinking time.

The instructor's design of active learning exercises was informed by her conception of active learning. The instructor highlighted the importance of designing the activities so that students are meaningfully engaging with the material and building their own understanding of the content. She explained:

> We teach them the very basics of how to use the software. And here is all the data that you are going to use and now go. In that second lab, it's just us walking around and asking questions because they have to build that mental model for that new problem they are solving or application that they are working on. It is on purpose designed that way so that they are building that new set of ideas. And then the reflection class. The questions that I have in their last assignment are really to get them to think about, what is the big picture, what's the big deal about the assignments that you did?

Furthermore, when asked about the challenges she faced when she first started using active learning, she acknowledged student resistance as a challenging aspect of active learning:

> I think students sometimes are not comfortable because it's easy for students to sit back and go to a lecture and be passive. And I think active learning gets some students very uncomfortable because they have to be there, not just physically but mentally. So I think initially some students are little bit shocked at the style of the class because it's something they are not used to, especially in engineering.

However, reflecting on her experience with active learning, the instructor reported the appropriate design of active learning as an important factor for overcoming student resistance. Specifically, she highlighted the importance of designing the activities so that they are relevant to students' learning and students are able to see the value of the activity, as evident in this comment:

> I think that you will always have students that are like, "I don't want to do this, I just want to do my homework assignments and that's it". But, once students see that they are actually learning more, and that going to class – "Oh, if I come to class, I am going to save time when I am doing my homework assignment and I am going to learn this thing better". And they are going to really get it and that's [student resistance] not going to be a big problem in the end eventually … it's a matter of really designing the activity so that the students get the message and understand why you are doing that, what's the big picture and why is it going to benefit them.

Furthermore, commenting on verbally informing students about the benefits of active learning as a recommended strategy for reducing student resistance, the instructor reported that students have to see the value of the activities themselves when they are participating and verbally informing them will not assist in mitigating student resistance, she said, "Verbally telling people, like, 'I am doing this for your own good'. And they are like, 'yeah, aha'. They have to see that they really learn the material better and say it saves them time doing their homework. They have to see the value. They have to feel it while they are doing it".

In addition to considering relevancy in the design process, the instructor also underlined the importance of designing activities which are appropriately complex to students' level of understanding. The instructor reported that she experienced student resistance when she first used project-based active learning and she changed the project by minimizing the scope of work from the first time in the subsequent course offerings. The instructor further elaborated on the importance of adjusting the complexity of active learning exercises for undergraduate courses:

> I learned the hard way because the first time I did this, [the project] was the whole building and it was a lot of work. And it was just too much for the students to do in a two weeks homework assignment. So I learned that the hard way and I scaled it down the next time I taught it. … So it's not everything, it's not too overwhelming.

Lastly, focusing on the workshop experience, the instructor suggested two improvements for workshop conveners. First, she suggested the inclusion of content-specific training in designing the active learning exercises in the first workshop. Contrasting with the advanced workshop, the instructor said,

> I think NETI 1 really gives you a taste of what active learning is. You do a very little. It's almost like you get a syllabus for class and you can think of one lecture. We do one break out session in one lecture on how to do active learning for that one lecture. So it's a very limited hands-on portion in NETI 1 … I don't think you get many opportunities to design those exercises. If we come up with five little exercises from NETI 1 that I could directly apply to my class, that would be great. That can get the ball rolling.

Second, the instructor underscored the benefit of attending the workshop with other faculty members teaching similar engineering courses. Elaborating on her NETI 1 workshop experience, she highlighted the benefits of breakout sessions in which she was able to work with other instructors who have taught similar courses, she said, “I had two other people who taught classes that I taught. But, I don’t know if everybody else had the same thing. Because I don’t know what other break out groups had. There must have been one person who had nobody to partner with. That’s the one limitation”.

In summary, the instructor responses highlighted the influence of her conceptions about active learning on the design and implementation of various exercises during the semester. Particularly, informed by the conception that active learning involves engagement in meaningful activities, the instructor designed the activities in accordance with course components that are relevant to students and adjusted the complexity to students’ preferred levels. Reiterating the importance of appropriate design of activities for its successful implementation, the instructor indicated the lack of opportunities to design active learning exercises as a limitation of the first workshop when compared to the second. In addition, she underscored the benefit of participating in the workshop with instructors having experience teaching similar courses.

Response to various active learning types

Although a positive response to active learning was observed through the semester, several variations in student engagement levels were noted among the different types of active learning exercises. Specifically, while Hands-on and Question and Answer Lab sessions consistently received high levels of engagement, variations in student engagement were observed within group discussion and presentation-based active learning exercises. In the focus groups, students highlighted the relevancy and complexity of various implemented activities as a reason behind variation in engagement. In the next sections, I describe student and instructor responses to the four types of active learning exercises implemented in the course. Table 5.5 presents an overview of engagement patterns for the four active learning types.

Table: 5.5 Student engagement to different active learning types

Type of Active Learning	Student Engagement	Student Resistance
Hands-On Lab	High for all the sessions	None
Question and Answer Lab	High for all the sessions	None
Group Discussions	Primarily low for most of the sessions	Passive resistance and Partial compliance
Student Presentations	Mixed and Low for most of the sessions	Passive resistance

Hands-On Lab Session

The hands-on lab sessions involved introduction to the software tool needed for completing the assigned project. Specifically, the session included demonstration from the teaching assistant about the functionality of the tool using a sample problem. Throughout the session, the students followed along on their own computer. The hands-on sessions lasted for approximately 120 minutes. The instructor frequently intervened during the demonstration to explain critical concepts and clarify students' doubts. A total of four hands-on lab session were held in the semester. For every session, the instructor demonstrated high levels of engagement by circulating around the room, monitoring students' progress and answering students' questions.

Student Response

High levels of student engagement were observed for the hands-on sessions for the entire semester. More than 90% of the class was observed to be engaged in the activity for almost every hands-on session. The students worked individually on their computers familiarizing themselves with the various software tools by following along the procedural steps demonstrated by the teaching assistant and explained by the instructor. In the focus groups, students provided positive feedback about the hands-on session. Students highlighted that the appropriate level of complexity of the exercise allowed them to complete it during class time. Particularly, students reported that the design of hands-on sessions in which a big problem was presented as a sequence of smaller steps allowed them to better understand the material. Students reported that performing the demonstrated steps on their computers assisted in understanding the process. For example, expressing satisfaction with the design of hands-on session, one student said, "I think I was fine with following along because it was like a lot of steps in such a short amount of time … we really needed the time to be able to understand each step to move on to the next one. Because then it would've been confusing if we did not understand the full process".

In addition, students provided positive feedback for the hands-on lab sessions due its relevancy with the lecture content and homework projects. The project involved direct application of software tools that were introduced in the hands-on lab session. The students reported that the sessions allowed them to learn about the course material by applying the content taught in the lectures. For example, commenting on the hands-on lab session, one student said, "She also has the teaching assistant to go through and teach us again, and walk us through how we apply those things we are learning".

A majority of the hands-on sessions involved only demonstrations where the students were expected to perform the demonstrated steps on their computers without additional exercises. However, in two instances the instructor engaged students further with the software tool. In the first instance, the instructor asked the students to "play around with the software" in addition to the demonstrations. Consequently, in this session, the students asked more questions and clarified more doubts when compared to the other sessions where they primarily followed along the demonstrated steps.

In the second instance, the instructor engaged the students in an in-class activity, in which she asked the students to work on a sample problem which was part of the project assignment for that week. The students demonstrated resistance to the activity by engaging in off task discussions in their groups instead of working on the assigned problem. However, the instructor was able to increase the participation by approaching disengaged groups and asking them if they have completed the activity or not. Overall, the activity received high engagement with almost every student engaged in the activity.

In the focus groups, students reported that they were tired after the lab session which is why they resisted the additional activity. Reflecting on the particular active learning instance, one student mentioned, "For me, that's a great example. I was like, 'I don't want to do this. I'll do this when I come back, when I am fresh. I am going to pick it up tomorrow but I am not doing it right now'". Another student echoed, "After 2 hour lecture or lab, that's not what I want to do. I'll do it later but not right now".

To summarize, student engagement remained high for the hands-on sessions throughout the semester. The design of the session in which the students performed the demonstrated process in steps on their computers emerged as a consistent positive feedback provided by the students. Students reported that this design allowed them to understand the project process and apply the content taught in lecture sessions during class time. However, there was a limit to their attention span. Students resisted the additional activity introduced in the session following the demonstration.

Instructor Response

In the interview, the instructor explained how she intentionally designed the course so that students are able to understand the basics of using the software during the hands-on sessions and then went to work on the project in later sessions. The instructor's response was in line with student focus group responses in which they expressed satisfaction with the design of hands-on sessions. In addition, consistent with student focus group responses, the instructor acknowledged that additional activity in the demonstration session overburdend the students due to limitations of time and complexity. Furthermore, with reference to the observed instance where she asked students to play around with the software, the instructor identified it as a strategy that she can more often use in the future.

To summarize, the overall level of observed engagement remained consistently high for hands-on sessions during the course of the semester. Student focus groups highlighted that the appropriate design of the session in terms feasibility of completion during class as a factor promoting student interest and engagement. Specifically, the step-by-step approach followed in the sessions allowed students to understand the process without overburdening them. The students consistently expressed satisfaction with the design of hands-on sessions due to its relevancy with lecture content and project assignments. The instructor interview response underlined how her design of the session matched with students' reported feedback. In other words, the alignment of the active learning session with students' preferred level of complexity and relevancy with other course components contributed towards high engagement. Every hands-on session was followed by a question and answer lab session in which the students worked on their projects using the software tools introduced in the hands-on session. In the next section, I report students' and instructor's response to Question and Answer Lab Sessions.

Question and Answer Lab Session

The Question and Answer Lab session allowed students to work on their projects in groups during class time under the instructor's guidance. The project deliverables were due a week after the question and answer session. A total of four question and answer lab sessions were held in the course. The sessions lasted for approximately 120 minutes. During the session, the instructor consistently encouraged the students by circulating around the room, monitoring students' progress and clarifying doubts. The instructor also encouraged interaction by asking students in one group to explain procedural steps and other project details to their neighboring groups. In addition, the instructor encouraged the students to meet her or the teaching assistant during office hours for help to resolve issues they are facing in completing the project.

Furthermore, the instructor utilized three noteworthy strategies to increase engagement. First, the instructor included certain tasks in the project deliverables requiring the students to find errors in the given model. Such tasks further assisted in increasing student engagement in the classroom. Second, the instructor approached disengaged students and asked them about their work and progress. Students who initially demonstrated resistance in the form of passive resistance began participating in the activity after instructor's intervention. Third, the instructor explained to students about parts of the assignment that can be completely individually and combined later. This facilitated engagement in class among students who were not able to engage in the activity due to the absence of their group members in the class session.

Student Response

Overall, high student engagement levels were observed during the sessions with almost every student working with their assigned group members. The students were engaged in the exercise almost for the entire session throughout the semester. During the sessions, students frequently raised their hands to ask questions to the instructor. Students' questions primarily involved clarifications about project deliverables, scope of the project and assumptions that they are allowed to make for modelling. In addition, students also engaged in questions inquiring about the specifications and models, indicating active involvement in understanding the project rather than only completing the assigned tasks. The instructor acknowledged this engagement and further encouraged students to ask such questions. At one such instance, the instructor announced, “Good you are asking these questions. It shows you are not just believing the numbers you are seeing”.

Although the students demonstrated high engagement, a few students were confused with the project, particularly for the first and last projects of the semester. The instructor noticed that the students were confused and helped students in two ways. First, she approached these students and provided additional assistance to them. Second, for the first and last project, she extended the submission deadline by a week and allowed students to work on their projects in the next class session. Student in-class feedback confirmed that the extension allowed them to understand the concepts as well as complete the project on time.

Student focus group findings indicated positive response to the projects and question and answer lab sessions. Specifically, students reported that they benefitted from working on the projects under the guidance of the instructor, as one student stated,

> This is my last semester now. In terms of homework, these are the most beneficial homeworks I have had. In terms of comparison with other courses, like these homeworks are much more beneficial than the other courses. You learn a lot. The homeworks are better put. In other homework, they will give you something and just do it. Here she was guiding us in some way. After the homework you would learn the objective.

Another student echoed,

> I think that it’s good to have the exercises. If you run into any problem, you can ask. In any case, in any course, if you give us the lecture and slides, we can do them without the

> instructor. But, at the end of the day, you want some integration within the course. Or having your thoughts put in there or you doing an exercise in class for it to be more engaging.

Student focus group findings indicated two reasons that led to high engagement. First, students highlighted the timing of the projects based on complexity as a reason for their success. Particularly, students appreciated that the complex and time consuming projects were introduced early in the semester. Commenting on the structure of the course, one student mentioned, “I am kind of glad the order that they have gone so far. I can’t imagine now going up against cost estimating and doing some of the things that were more time intensive. These now are less difficult seeming. I think she structured this in a way it’s not overwhelming”. Reflecting on the time constraints prevalent at the end of semester, one student stated, “Complex projects should be as early as possible”. Another student reiterated, “During this time it’s like finals, everything is due in these last few weeks. It’s more difficult to meet with your partners”.

Second, the students reported that the level of complexity of the projects was appropriate for them to remain encouraged and engaged in the project, as evident in this student comment: “I think it’s just the way professors integrate and hold the attention of their students. They have to I think find that balance of challenging them enough so they learn the material but not so much that they are freaking out that it’s so hard and complex”.

Although student engagement consistently remained high during the semester, variations in student interaction were observed between the projects. Specifically, in the cases of the first and last projects, the students also interacted outside their assigned groups to clarify doubts and discuss other details about the project during the hands-on session. In contrast, for the other projects in the semester, less interaction between the student groups was observed. This can be attributed to the complexity of projects. Projects which were more complex lead to higher inter-group interaction, while projects which were comparatively less complex involved students working individually or within their assigned groups.

Student focus group response underscored the complexity of the project as the reason behind variation in engagement. For example, one student mentioned, “First project was hard, everyone is trying to figure out how to do all this. So there was a lot of like – what were the errors and we were comparing to make sure we were on the right track and I think as we went on it became less difficult and less comparison”. Table 5.6 summarizes the student response to question and answer lab sessions.

Table 5.6: Student Response to Question and Answer Lab Session

Complexity of project	Student Engagement Level	Student interaction	Student Resistance
Moderate	High	Within the assigned group	None
Difficult	High	Within the assigned group and between groups	None

Instructor Response

During the class session, at multiple instances, the instructor sought feedback from students about each project. Specifically, the instructor asked about the complexity of the project and the number of hours students worked to complete the project. The instructor used this feedback to design the projects, she mentioned, "I had to be a lot more careful about the size of the homework assignments as well. I try to keep them around 10 hours. That is why I always ask the students how long did you all take to do this".

In the interview, the instructor highlighted that she considered these two factors while designing the projects. First, the instructor reported that she included complex and time consuming projects earlier in the semester, which led to high engagement. The instructor mentioned, "All of my classes tend to be front loaded. It's really heavy in the first half of the semester. They got to get all that work done while I have their energy. And in the second half of the semester, its natural, everybody is going to be exhausted". Furthermore, the instructor reported that she used student feedback about the projects for designing the project sequence for next semester. Referring to the last project which she implemented in this class for the first time, she stated "For the last one, I did not know that it would take so long for them to do it. So the next time we do the class, that's going to be the third assignment."

Second, in response to questions asking about the process behind the design of the projects, the instructor underscored the importance of scaling the complexity of the projects to align with students' level of understanding. Reflecting on her first experience teaching this course, the instructor reported that she did not appropriately choose the complexity of the project which led to students being overwhelmed with the project. Consequently, in the next course offerings, she scaled down the complexity of the project by minimizing the scope of work.

In summary, similar to the hands-on session, student engagement also remained high during the Question and Answer Lab sessions. Student responses indicated appropriate sequencing of the projects and the appropriate choice of complexity as reasons behind high engagement. The instructor's reflection on prior experiences highlighted the importance of alignment and strategies for achieving this alignment. Particularly, the instructor suggested, 1) Gathering feedback about the time used by students to complete the project, 2) Using the feedback to reducing the work load and deliverables and 3) Using feedback to inform sequencing of projects. Lastly, it is worth noting, while the sequencing of complex projects at beginning of the semester led to high engagement, inter-group interaction declined with reduction in complexity.

Group Discussions

The group discussions held during the semester were primarily based on readings which were assigned a week before class. The instructor initiated discussion by posing multiple questions to the whole class based on the assigned reading. During the activity, the instructor did not circulate around the room, but encouraged students to participate by asking questions multiple times to the students. Such activities lasted for approximately 8-10 minutes. In addition, the instructor also introduced discussion in think-pair-share format in which the students were asked to work on an assigned problem with their neighbors and then discussed their answers with the whole class. Variations in student engagement were observed based on the type of discussion. The next section discusses student response to the different discussion-based activities introduced in the semester.

Student Response

The *reading-based discussion* activities received low to mixed levels of engagement with approximately half of the students engaged in the activity. Only a small subset of students who were usually active in discussions volunteered to share their answers and comments on the posed topic with the class. The students primarily demonstrated passive resistance by sitting idle and refusing to engage in the class discussion. Students mostly focused on writing the summary points or taking notes about the reading rather than engaging in discussions. At multiple instances, students also demonstrated partial compliance. Students copied key points from the lecture slides on their electronic devices and from each other, rather than fully engaging in the discussion.

Student focus group findings revealed the choice of readings as the reason behind student resistance. Particularly, the students expressed concerns about the length and complexity of the assigned articles, as evident in this student comment: “The problem with reading is that they are sometimes too long. You just don’t have time to read it ahead of time. If the reading is like 4-5 pages, its fine. When I open the pdf, first thing I look at is number of pages. If it’s anything beyond 7, I am like, ‘I am not going to read this’”.

Expressing the difficulty faced in understanding the assigned readings, one student stated,

> I think nobody wanted to read because they were around 10 pages each. They were mostly like case studies and journal articles and scholarly papers. On top of the length and the time it took, some were really hard to follow along with. The technical terms they

> used. Even when I would read, I would get more out of what she thought about the reading than when I actually read the reading itself.

Although student engagement remained mostly low for reading-based discussion activities, high engagement levels were observed in two instances. In the first instance, contrary to other discussion activities, the assigned reading for the class discussion was more directly relevant to the assigned project. At the beginning of the activity, the instructor explained how the reading related to the project and discussed how parts of the assigned reading will be helpful in completing the project tasks. This particular instance received high student engagement with more than 90% of the class engaged in the activity. During the discussion, the students expressed their answers to the posed questions without additional encouragement from the instructor. Student focus group responses reaffirmed the relevancy of this reading with the assigned homework problem as the reason behind increase in engagement. One student commented, “Some of them were. One of it was really used in the false positives. Some readings were actually part of the homework so we had to know it”. Highlighting the irrelevancy of other readings to the homework, one student commented, “I also didn’t read most of readings before going to class, but I did read them for the quiz. I don’t know how beneficial they were. I feel like it didn’t really help with the homework”.

In the second instance, comparatively higher engagement levels were observed when the assigned reading was a white paper rather than a journal article. Students reported the appropriate complexity and length of white papers as reasons behind increased engagement. Contrasting the white paper with other assigned readings, one student mentioned, “Even the papers, they have like, every page is two columns, and with small font and stuff. So if we actually put them on a word paper it turns out to be like more than ten or fifteen pages. So, it will be much easier if we read the white papers, it will be shorter and less technical I guess". Another student reiterated, "It [White Paper] was shorter. It was just three pages, where a technical report is 10 pages. We could get a good picture of what the topic was about without too much detail".

On the other hand, the *problem-based discussion* activity which was held once in the semester, received high engagement from the students. The discussion was implemented in the form of think-pair-share in which the instructor asked the students to work on an assigned problem with their neighbors and then discuss their answers with the whole class. During the activity, the instructor demonstrated high participation by circulating around the room, looking over student work and encouraging students to discuss the answers with their neighbors. A majority of the class was fully engaged in the activity. Particularly, the students who were resistant in the reading-based discussion, demonstrated high engagement in this active learning exercise. In addition, these students also volunteered to share their solutions at the end of the activity. At the end of activity, the instructor explained to the students how this particular exercise will be useful in completing the project assignment.

In the student survey, for most of the listed active learning activities, a majority of the students indicated that they would prefer the same or more of these activities in their ideal course. However, contrary to other implemented activities, student preference for activities requiring preview of concepts before class by reading and watching videos remained low, which is consistent with student response received when the survey was administered in other courses. For example, while more than 70% students indicated that they wanted the same or more of different active learning types (e.g. Work in assigned groups to complete homework or other projects or Do hands-on group activities during class), 72% students indicated that they wanted less of reading-based activities. Table 5.7 lists students' ideal course preferences for the various activities.

Table 5.7: Student Instructional preference in their ideal course (n=18)

For each of the following things, please indicate how often you would like to do each in your ideal course.	Much Less	Slightly Less	About the same	Slightly More	Much More
Work in assigned groups to complete homework or other projects.	17%	11%	50%	5%	17%
Make individual presentations to the class.	5%	0%	39%	39%	17%
Discuss concepts with classmates during class.	0%	11%	50%	22%	17%
Preview concepts before class by reading, watching videos, etc.	22%	50%	17%	6%	5%
Solve problems in a group during class.	0%	17%	33%	33%	17%
Solve problems individually during class.	0%	11%	33%	39%	17%
Answer questions posed by the instructor during class.	0%	11%	44%	17%	28%
Do hands-on group activities during class.	6%	11%	22%	44%	17%

Instructor Response

In the interview, the instructor acknowledged the comparatively lower levels of engagement received in reading-based discussions, she stated, "Some of them wing it before class. You can tell that they are skimming it desperately or even skimming during [discussion] on their desktops”. The reluctance of students to participate in the discussions was also noticeable in instructor’s in-class behavior. In multiple instances, the instructor asked students who have not spoken to share their group discussion. In one instance, the instructor called upon a group of disengaged students and asked, “Did you guys come up with anything?”. At another instance, upon noticing the lack of student response, the instructor commented, “You guys didn’t get the time to get to the last paradigm in your 8 minutes?”. In spite of the instructor’s encouragement and intervention, resistant students did not engage in the discussion, and only a few usually active students volunteered to share their responses. For the problem solving exercise, the instructor mentioned that she did not design it as other active learning components used in class rather she had been using it based on her past teaching experience.

The instructor interview response highlighted the influence of her conceptions about articles behind the selection of readings. Specifically, the instructor’s intention of providing a broad understanding of the content led to the selection of journal articles as reading assignments, which is evident in this comment:

> I tend to pick the readings, first of all based on what I think will give them a broad understanding of the picture of the application ... I think the journal articles are a little more detailed. They talk about the research process, about how somebody conducted it, so there is more detail, so there is more content to cover.

Furthermore, contrasting journal articles with white papers, she expressed:

> The white papers are more, 'here is all the cool stuff that can be done'. So it's very superficial. So that's why I don't have them. I wouldn't have all white papers, I could have all journal papers in the class, I could see that. But, I wouldn't have all white papers … The white papers from industry, I think it's too superficial. It's almost like a potpourri. Two pages of a potpourri of technologies. But it's not really in depth.

In other words, while the students expressed concerns about the readability and complexity of journal articles in the focus groups, the instructor held the conception that journal articles provided deeper understanding when compared to white papers. Furthermore, when presented with the observational and focus group findings, the instructor acknowledged it as good feedback and reported that she will use simpler readings in future course offerings. Thus, in contrast to Hands-On and Question and Answer Lab sessions, student engagement remained lower for discussions primarily due to the misalignment between students' preferences and instructor's conceptions about the complexity and relevancy of the active learning exercise. Table 5.8 summarizes student engagement for discussion-based active learning exercises.

Table 5.8: Student engagement in Group Discussions

Type of Discussions	**Type of reading/posed problem**	**Student Engagement Levels**	**Student Resistance**
Reading-based	Journal article and irrelevant to homework	Low/Mixed	Passive, Partial Compliance
	Journal article but relevant to homework	High	None
	White paper	High	None
Problem - based	Relevant to homework	High	None

Student Presentations

Student presentations required students to present their project and case study work in their designated groups. While the projects were common to all the students in the class, the case studies were specific to every group. Each student group presented once about the project and once about the case study during the semester. Two presentation sessions were held in a class session and each presentation lasted for approximately 20 minutes. A total of 8 presentation sessions each for projects and case studies were held in the semester. Two student groups presented for each of the four course projects, totaling to eight project presentations in the semester. For case study, each of the eight student groups presented on their individual topics, totaling to eight case study presentations in the semester.

During the presentation sessions, the instructor asked the students to turn off their computer screens. In addition, the instructor provided the presenters with few pre-specified points and questions that they were asked to address in their presentations. Such questions led to high engagement in the audience during the presentation. For example, in one such instance, upon the instructor's direction, the presenters posed a question to the audience which could be answered in multiple ways. This led to increased engagement with several students contributing and expressing their ideas about the posed questions. During the class session, the instructor mentioned that she included this question so that she "can pick your brains".

In addition, during the presentations, the instructor interrupted at multiple instances, posing questions to the whole class, commenting on key points presented by the students, asking how other groups approached the problem and suggestions for improvements. Students acknowledged the contribution of these questions to higher engagement, as evident in this student comment: “It’s also about questions. How did you do this and is there a better way to do it? Everyone wants an easier and better way to do something. So, when it’s that type of discussion, I think more people want to participate because you are getting something out of it”.

In general, mixed to low engagement levels were observed for presentation sessions. Project presentations received higher student engagement when compared to case study presentations for most of the sessions. However, high engagement levels were noted at multiple instances for both case study and project presentations, in which the presenting students posed questions to the students in the audience. The next sections provide a detailed description of classroom observations, student focus group results and subsequent instructor response for presentation-based active learning exercises implemented in the semester.

Student Response

In case of *project presentations*, overall mixed level of engagement was observed with approximately 60 – 70 % students engaging in the instructor-initiated discussions. The other students demonstrated passive resistance by not participating in the discussion. At the beginning of presentation sessions, the instructor announced that she expected the students to ask questions because all the students have worked on the same project problem. At multiple instances, the instructor encouraged the students in the discussion by asking for student questions and comments.

In the focus groups, students provided positive feedback to project presentations and identified relevancy of the project as a reason behind higher engagement. For example, one student said, “Everyone’s done it. It’s not like someone is coming with a specific topic assigned and they are trying to teach the class something and you are just kind of zoned out because it means nothing to what you have done. Everyone has done it, you feel like you have something to contribute.”

Highlighting the relevancy of presentations towards their learning, another student mentioned, “For me it was nice because I could actually see what other groups did and compare what they did to yours. I don’t think it took too much time, just doing a presentation, and a PowerPoint, and actually performing in the class doesn’t take too much time”.

In addition, the students also recognized the usefulness of presentations in their future job responsibilities. Underscoring the advantages of knowing how other students performed the project task with focus on future work responsibilities, one student commented,

> I think it was good because that just like the extra information that we don’t get directly from like the actual assignment. Because we collaborate when doing the assignment but not to a point where it’s like specific improvements on how to like be more efficient in the assignment. For some people we might actually be using it after this class if we go into construction engineering. So, I would want to know what other people did so that way if I ever have to use this program again, I can actually know of a shortcut.

On the other hand, *case study presentations* consistently received low levels of student engagement with less than half of the class engaged in the activity. Students demonstrated resistance primarily in the form of passive resistance in which they refused to engage in follow-up discussions. Students often engaged in off task activities on their electronic devices and expressed negative body language by siting with their heads down on the table. The case study presentations lasted for approximately 20 minutes. During the presentation, the instructor commented on the case study and highlighted key points. At multiple instances, the instructor posed questions for discussions and encouraged students to ask questions. In spite of the instructor's insistence, a majority of the students did not ask questions nor engaged in discussion after the presentation.

In the focus groups, students reported relevance of the project presentations as reasons for high engagement when compared to case studies. For example, one student mentioned, "I think for homework, we all have done the same thing. So we have more to talk about, more problems that we all encountered. Case studies, every group has different topics, at least different cases, so they face different problems. So, there is probably not much to share".

Another student echoed,

> Case studies were specific. I mean all of us were doing the same homework, we had the same outline, and even the deliverables were same. So everyone had gone through the process, everyone could relate to what the group is presenting. But when you are talking about the case study, it's case specific. So, what we three guys know, that's something others won't know.

For both project and case study presentations, high levels of student engagement were observed at multiple instances in which the students presenting posed questions to the students in the audience. The questions usually asked other students about the difficulties they faced and approaches they used to solve different issues related to the project. A high engagement level was observed in response to such student-initiated discussions for both project and case study presentations, in which a majority of the students volunteered to express their used approaches and participated in the discussion.

Student focus group responses identified two reasons behind high student engagement. First, students reported that they felt more comfortable answering questions posed by students when compared to the instructor. As one student mentioned,

> I would say I feel more comfortable responding to a question posed by a student because if you are asked a question by a teacher and you get it wrong, it's really embarrassing. But, if you are asked a question by a student, you kind of know, like, 'I can answer because neither of us are perfect because we both are still learning'. So it's just more comfortable way of opening up the classroom for discussion I suppose.

Second, students expressed that they felt more responsible to answer student-initiated questions than instructor-initiated questions, as evident in this student comment, "I think there is also something, when a fellow student asks a questions, you do want to like come to their aid and not let them hanging. While for professor, you are really accustomed to having them ask questions and have them beat that silence. So there is a little bit of empathy in there."

Instructor Response

In alignment with students' focus group responses, the instructor's interview response underscored the importance of relevancy of the exercise to students' learning as a reason behind high student engagement. She mentioned, "You need to understand that everybody did that same assignment as you did, so they will be able to understand all that you are talking about … They understand everything in detail. So, they are expected to chime in their thoughts".

When informed about the observed variation in student engagement in instances of student initiated questions, the instructor reported that she intentionally included that component in the presentation exercise, she mentioned,

> The presenters have to understand that it's part of their role, and I tell them when they are presenting, you have to prompt the audience to participate. It's your job as a presenter to ask those questions ... It's not graded. I just informally, like the class before they are presenting, I usually walk up to the group and say you are presenting in next class, try not to have slides that are wordy and try to engage your audience. I just informally chat with them about that.

In summary, the level of engagement for student presentations varied with the relevancy of presented topics to the students. While project presentations received higher student engagement than case study presentations, high engagement levels were observed for student initiated questions for both type of presentations. Student responses indicated relevancy of project presentations when compared to case study as a reason behind higher engagement. In addition, the instructors' interview response indicated alignment with students' responses. Lastly, students' responses also highlighted the use of student-initiated questions as an effective strategy for engaging students in the audience in presentation-based exercises. Table 5.9 presents summary of presentation-based active learning exercises.

Table: 5.9 Student response to presentations

Type of Presentations	**Type of questions**	**Student Engagement Levels**	**Student Resistance**
Project	Faculty-Initiated	Mixed	Passive
	Student-Initiated	High	None
Case Study	Faculty-Initiated	Low	Passive
	Student-Initiated	High	None

Summary

In this case study, the overall observed level of student engagement remained high for most of the active learning exercises during the semester. Student survey responses confirmed observed engagement levels. Approximately 90% of the students reported that they actively participated and tried their hardest to do a good job in the activities for majority of the time. Also, a majority of the students reported that they rarely demonstrated resistance during the activities. In addition, in the focus groups, the students reported that they felt positively towards active learning-based instruction and saw the value in the activities. The survey responses further validated students' positive emotional and value response. In the survey, students reported that they saw the value and acknowledged the benefits of the activities to their learning.

Although high student engagement was observed for most of the active learning exercises, variations in engagement were noted between and within the active learning types implemented during the semester. Alignment of the activities with students' preferred level of complexity and relevancy to course components important to students (exams and homework) emerged as a primary reason behind variation in student engagement. Particularly, Hands-on and Question and Answer lab sessions consistently received high engagement due to the appropriate choice of complexity of the activities and their relevance to course homework. This appropriate design was because the instructor carefully monitored student feedback and modified the activities over years of instruction.

On the other hand, discussion and presentation-based active learning exercises received comparatively lower levels of engagement. Student responses indicated lack of relevancy to assigned projects and homework as a reason behind lower engagement levels. Lower student engagement levels were observed for discussions in which the readings were complex or the discussion was not directly applicable to the assigned homework. For example, journal article discussions received lower engagement when compared to white paper and problem solving discussions, which the students reported as adequately complex and relevant to their learning. Similarly, due to their relevancy, project presentations resulted in higher student engagement than case study presentations.

The focus group responses provided further insights about the reasons behind high student engagement. Specifically, in addition to structuring of the course and use of a variety of active learning techniques, the students consistently reported the relevancy and appropriate complexity of active learning exercises as reasons behind high engagement. The activities which were relevant and appropriately complex received high engagement. In other words, due to the effective design of the active learning exercises in terms of relevancy and complexity, students positively responded to active learning during the semester.

Furthermore, the instructor response demonstrated consistency with student feedback and further elaborated the aspects of active learning design that help in promoting student engagement. Particularly, the instructor reiterated the importance of designing the activities so that they are relevant to other course components such as homework and are appropriately complex for the students to engage meaningfully without being overburdened. However, due to misalignment with students' preferred levels of complexity and lack of student feedback on the assigned readings from prior semesters, the journal article discussions received low engagement throughout the semester.

Finally, in regard to the faculty development workshop, the instructor highlighted the lack of opportunities to design usable active learning exercises in the first workshop. She underscored the importance of including content specific training for designing the active learning exercises and opportunities to engage in the design process with instructors having experience teaching similar engineering courses.

VI. Chapter Six: Conclusion, Discussion and Future Work

Conclusion and Discussion

The guiding framework presented the instructor's conceptions, faculty development and student presage as factors influencing classroom instruction (Light, Calkins, Luna, & Drane, 2009). In line with the guiding framework, in this study, I found the influence of the three factors on the implementation of active learning in the classroom. While the influence of the instructors' conceptions was evident in their implementation of active learning in the two cases, different faculty development workshop experiences further contributed to the variation in the design of active learning exercises. Furthermore, variations in student engagement were observed between the two cases due to differences in the design and implementation of various active learning exercises. In the next sections, I describe the three factors with regard to the findings of the two case studies and present implications for faculty developers and engineering instructors.

Instructor Conceptions

The influence of the instructors' conceptions is widely acknowledged as a critical factor determining the effective implementation of research-based instructional practices (Borrego, Froyd, Henderson, Cutler, & Prince, 2013; Kember, 1997; McAlpine & Weston, 2000; Yerrick, Parke, & Nugent, 1997; Yerushalmi, Henderson, Heller, Heller, & Kuo, 2007). Although instructors are able to incorporate several research-based pedagogical aspects into their instruction, there exists a lack of full adoption of research informed curricula (Henderson, Heller, Heller, Kuo, & Yerushalmi, 2002). Researchers have reported that instructors often did not fully use the research-based curricula, rather they choose to implement parts of it based on their instructional and personal preferences (Henderson & Dancy, 2005). In line with existing research, I found the influence of instructors' conceptions about active learning on the design and selection of various active learning exercises.

In the first case study, I found that after attending the workshop, the instructor selected and used only discussion-based active learning exercises. This selection was informed by his conception about active learning. The instructor's conception that questions with right or wrong answers are not in line with active learning led to the selection of broad questions for the discussion-based activities. Due to their broadness and disconnect with homework or exam problems, discussion questions were reported by the students as the primary cause behind their disengagement in the active learning exercises.

On the other hand, in the second case study, the influence of the instructor's conception about active learning, emphasizing the importance of learning through engagement in classroom exercises, was evident in the design and selection of various active learning exercises. Most of the active learning exercises implemented were designed to help students learn the course material through engagement in the classroom. The hands-on sessions equipped the students to work effectively on their projects and engage in subsequent question and answer lab sessions. The design of projects in accordance with students' level of understanding facilitated engagement in the question and answer sessions, in which they completed the project tasks under the guidance of the instructor. The project presentations encouraged further discussion among the students about the project. In other words, the use of a variety of active learning techniques, their appropriate design and sequencing, were reported by students as the reasons for high engagement, which was observed for a majority of the instances throughout the semester.

Researchers have suggested that teaching practice may not reflect the intentions of an instructional strategy's developers (Froyd, Borrego, Cutler, Prince, & Henderson, 2013). Consistent with the suggestions, I found that the implementation of active learning was not reflective of developer's intentions in the first case study. The instructor emphasized active learning as a means to increase classroom interaction, all but ignoring definitions of active learning which place due emphasis on engaging in meaningful activities that enhance learning (Bonwell & Eison, 1991; Prince, 2004). In the second case study, the instructor acknowledged the importance of engaging students in meaningful activities in an active learning classroom, which guided the design of various activities used in the course. Interaction followed naturally from an emphasis on authentic engineering practices.

In a recent study examining faculty perceived benefits of flipped classrooms, Zappe, Litzinger, and Yan (2015) reported that the two most frequently cited benefits about active learning by instructors were student interaction and engagement. In addition, in spite of alignment in beliefs that problem solving is conducive to student learning, Borrego et al. (2013) found that engineering instructors were reluctant to devote more class time to active learning including problem solving. One plausible explanation could be that instructors believe that class time devoted to active learning is not when learning takes place and consider active learning more of a tool for increasing classroom interaction rather than a technique aiding student learning. Faculty members are usually unfamiliar with educational research and its pedagogical implications (Marra, 2005).Workshop participation may have limited results if " the underlying beliefs of the participants are inconsistent with the conceptual framework of the initiative" (Kember, 1997, p. 272). Thus, along with the dissemination of research-based instructional techniques such as active learning, faculty development efforts should simultaneously educate instructors about their pedagogical implications to facilitate effective adoption. Workshops and other efforts may need to focus more effort on changing fundamental conceptions about student learning. The conveners should educate instructors about the benefits of meaningful engagement with the course content during class time in improving student learning.

Faculty Development

Due to the lack of formal training, instructors are often not aware about active learning methods (Bransford, Brown, & Cocking, 1999; Felder, Brent, & Prince, 2011; Fox & Hackerman, 2002; PCAST, 2012; Tanner & Allen, 2006). Faculty professional development programs have been recommended to train engineering instructors about active learning (Felder et al., 2011; Jamieson & Lohmann, 2012; PCAST, 2012). In line with prior research (Lattuca, Terenzini, & Volkwein, 2006), both the instructors in this study incorporated active learning based teaching methods in their courses after attending the workshop. However, different workshop experiences of the two instructors influenced the implementation of active learning and subsequent student engagement in their classrooms.

Specifically, in the first case study, the instructor struggled in designing active learning exercises after attending NETI 1 workshop. He described the challenge he faced in designing the active learning exercises and expressed the need for more support and training in developing content-specific questions for active learning in the NETI 1 workshop. In the second case study, the instructor was able to appropriately design and implement various active learning exercises and received high student engagement throughout the semester. Based on the NETI 1 and NETI 2 workshop experience, she expressed the lack of opportunities to design active learning exercises as a limitation of the first workshop.

Teaching workshops are influential in increasing instructors' knowledge about research-based teaching methods. However, in spite of increased awareness, researchers have reported that engineering instructors who tried active learning have discontinued its use (Cutler, Borrego, Henderson, Prince, & Froyd, 2012). It is likely that few instructors will attend both the workshops. This might lead to inappropriate design of activities and contribute to student resistance (disengagement) as observed in the first case study. Student resistance has been noted as a major barrier to adoption of active learning by researchers (Cutler et al., 2012; Dancy & Henderson, 2010; Finelli, Richardson, & Daly, 2013; Froyd et al., 2013; Prince et al., 2014), engineering faculty developers (Felder, 2011; Felder & Brent, 1996, 2010) and past workshop attendees (Ssemakula, 2001). Thus, considering the importance of appropriate design of active learning exercises for successful implementation, workshop conveners may include more design-specific training in the first workshop itself.

While researchers have recommended faculty developers to help instructors design in-class activities (Borrego et al., 2013; Prince, Borrego, Henderson, Cutler, & Froyd, 2014), the findings point out specific attributes that engineering instructors should to be assisted with. First, considering the quantitative nature of engineering courses, instructors should be helped in selection and design questions of suitable complexity and relevancy to exam problems for discussion-based active learning. Second, considering the complexity of quantitative problems in engineering courses, instructors should be coached in transforming homework and exam problems into smaller ones which students are able to solve in a short time during class. In other words, more effort might be focused on helping engineering instructors translate complex quantitative problems into appropriate, brief active learning exercises. Since this has not been addressed previously, it may be accomplished through some general design rules or heuristics applicable across engineering disciplines followed by time for individuals to reflect and apply it in their own settings.

In addition, faculty developers have advocated the effectiveness of workshops conducted by experts with same disciplinary backgrounds as that of the participants (Felder et al., 2011). Existing faculty development efforts usually treat participants as a single entity of engineering instructors without considering their departmental and disciplinary differences. In the first case study, the instructor expressed concerns regarding the lack of opportunities to interact with other faculty members from similar engineering disciplinary backgrounds such as electrical or civil engineering. In the second case study, the instructor mentioned the benefit she received of attending workshops with other faculty members teaching similar engineering courses.

Engineering education researchers have called for more targeted professional development efforts which bring faculty together (Chen, Lattuca, & Hamilton, 2008). Also, engineering instructors are more likely to interact within their research-specific communities. Engagement with peers has been suggested as an enabling factor for increased adoption of active learning (Froyd et al., 2013; Prince et al., 2014). Networking and community building facilitates the adoption of active learning (Finelli, Daly, & Richardson, 2014). In other words, disciplinary content-specific pedagogical training will not only help instructors design active learning exercises for their classrooms but also simultaneously foster a community of practitioners who can share among themselves their research as well as teaching experiences. Thus, engineering faculty development initiatives might consider specializing more specifically within engineering disciplines. The Exceed Workshop conducted by American Society of Civil Engineers is an example of an engineering discipline-specific workshop that may serve as platform for promoting active learning among civil engineering instructors.

Lastly, an interesting finding of this study is that in both the cases the instructors attributed an active learning activity to their prior experiences than the workshop. In both cases, these activities received high student engagement. In the first case study, the instructor attributed the problem solving activity which received no student resistance to his prior teaching experience and not the workshop. Similarly, in the second case study, the instructor reported that the problem solving-based discussion which received high levels of engagement was not designed as other active learning components used in class and was rather based on her past teaching experience. Although the use of active learning is scarce among engineering instructors, it is likely that instructors might have some elements which have not been introduced as an activity (e.g. questions posed during lecture without giving enough time for discussion), but have the potential to be transformed into an active learning exercise. Faculty developers should capitalize on such elements to train instructors, facilitating the use of active learning. Thus, workshops might follow a more constructivist approach in allowing instructors to draw on their prior teaching successes to recognize when and how they may have already implemented active learning or other evidence-based teaching practices.

Student Presage Factors

Student resistance is a major barrier to engineering instructors' adoption and continued use of active learning (Cutler et al., 2012). Although in the first case study the instructor continued the use of active learning throughout the semester, workshop attendees might receive negative student responses, which could negatively affect their teaching evaluations and discourage them from using active learning (Felder & Brent, 2010). Thus, to increase adoption and encourage continued use, instructors should be assisted in overcoming student resistance. The results of this study demonstrate that instructors can overcome resistance through specific strategies.

The findings suggest that the students were not resistant to the idea of active engagement, rather it was the design of the exercises that hindered the effective implementation of active learning. In the first case study, contrary to the problem solving exercise, the discussion activities received student resistance due to the type of questions posed during the discussion. Students reported the complexity of posed questions and their irrelevancy to other course components important to students (e.g. exams and homework problems) as reasons behind their resistance. Survey responses indicated that students who preferred more problem solving activities responded negatively to discussion.

In the second case study, the overall engagement remained high for a majority of the active learning exercises and there was minimal resistance. The students reported that the implemented exercises were relevant to their learning and adequately complex for them to engage effectively. However, variations in student engagement were observed due to relevancy and complexity of the active learning exercises. Specifically, lower engagement levels were received in multiple active learning instances in which the students found the exercises either irrelevant to other course components such as homework or too complex for them to understand. For example, discussions in which the assigned readings were journal articles received lower levels of engagement when compared to white papers and problem solving exercise-based discussions.

Students often perceive that active learning does not contribute to their learning (Lake, 2001; Yadav, Subedi, Lunderberg, & Bunting, 2011). In addition, students' perceptions of the relevance of active learning contributes to their perceived value of the course (Wilke, 2003). The findings of this study identify complexity and relevancy of the active learning exercises as two important factors influencing student resistance. Specifically, the results identify misalignment between the activities and course components important to students (homework and exams) as one plausible reason behind student resistance, reiterating the need for assisting instructors in the design of active learning exercises. In addition, the findings suggest that engineering instructors should consider the level of complexity appropriately for their students while designing the active learning exercises. Faculty developers should publicize the importance of considering the two factors while using active learning techniques and provide assistance in designing active learning exercises to workshop participants.

Lastly, the findings of this study suggest several strategies that instructors may use to promote student engagement in active learning classrooms. In the next sections, I describe the strategies for promoting engagement in student presentation, reading and project-based active learning exercises. These activities are often recommended to promote student learning in engineering classrooms.

Student presentations serve as an instructional platform for enhancing engineering students' professional, communication and technical skills (Kågesten & Engelbrecht, 2007; Koehn, 2001; Kunioshi, Noguchi, Hayashi, & Tojo, 2012; Sageev & Romanowski, 2001). However, when compared to other instructional methods, college students often rank classroom presentations unfavorably (Sander, Sanders, & Stevenson, 2002; Sander, Stevenson, King, & Coates, 2000). While student presentations and follow up question and answer sessions provide an avenue for student engagement with the content, student disinterest in the topic can lead to low engagement in such sessions (Pineda, 1999). Furthermore, students may also remain passive during the follow up sessions fearing embarrassment (Pineda, 1999). Instructors should create a classroom environment in which course components such as presentations serve meaningful functions (Paretti, 2008). The findings of this study suggest two strategies for promoting engagement in presentation sessions. First, in order to create student interest in the presentations, the instructor should assign homework or projects which are common to all the students as presentation topics. Since repetitive project presentations may lead to disengagement, the instructors should assign one or two student groups to present on the different projects instead of requiring every group to give presentations on every project. This will assure that every student gets an opportunity to present during the semester and the presentations are not repetitive. This will not only allow the students to understand the presentation but also allow them to engage meaningfully in the follow-up discussions. Second, instructors should use student-initiated questions to encourage student participation. Questions posed by the presenting students to the audience may encourage students fearing embarrassment to participate in follow up discussion sessions.

Assigned readings are recommended in active learning classrooms to initiate discussions (Felder & Brent, 1999) and are often used in flipped classroom approaches (Mason, Shuman, & Cook, 2013). However, college students often demonstrate resistance to reading assignments by not reading the assigned readings (Lei, Bartlett, Gorney, & Herschbach, 2010; Sappington, Kinsey, & Munsayac, 2002). This resistance to reading assignments diminishes the effectiveness of classroom discussions (Sappington et al., 2002). Researchers have noted several factors that influence student compliance to reading assignments such as time required to complete the reading, difficulty of the reading material and relevance to subject matter (Brost & Bradley, 2006). In line with existing research, in this study, I found that students demonstrated resistance to reading-based discussions and expressed concerns about the complexity and relevancy of the assigned articles. Students reported that they had to devote a lot of time to reading and understanding the journal articles. Thus, to encourage students to read the assigned articles and engage meaningfully in classroom discussions, instructors may use white papers or other simpler articles rather than journal articles in reading based activities or provide further assistance to students in understanding the complex readings.

Project-based learning allows students to enhance their technical and practical skills by working in teams on real world projects (Frank, Lavy, & Elata, 2003; Macías-Guarasa, Montero, San-

Segundo, Araujo, & Nieto-Taladriz, 2006). Engineering education researchers and faculty developers have recommended the use of project-based learning in engineering courses (Edward, 2004; Iscioglu & Kale, 2010; Lou, Liu, Shih, Chuang, & Tseng, 2011; Palmer & Hall, 2011; Prince & Felder, 2006). However, in spite of learning gains, student perceptions of the instructional approach have not been positive. Researchers have reported that students perceive project-based learning as overwhelming which leads to discomfort among students (Savage, Chen, & Vanasupa, 2007; Yadav et al., 2011). Appropriately challenging activities are influential in promoting student engagement (Armbruster, Patel, Johnson, & Weiss, 2009). The findings of this study identify three strategies that instructors may consider when using project-based learning. First, in order to reduce student discomfort, instructors should optimize the complexity of the projects by adjusting the scope of the projects based on student feedback. Instructors can use student feedback such as the time required for project completion, to monitor the scope of the project. Second, sequencing complex and time-consuming projects earlier in the semester is another strategy that instructors may use in project-based learning classrooms. Researchers have noted that activities implemented in the end of the semester receive less student interest due to limited time (Wilke, 2003). Third, in order to create an effective learning environment, instructors should make sure that students are trained and possess required background knowledge to complete the assigned project tasks (Frank et al., 2003). The instructor may use demonstration sessions where students follow along sample problems in class before working on their assigned projects. Providing such opportunities will not only equip students with the needed skills but also encourage further inquiry by allow students to explore software tools or other project equipment.

Future Work

This study examined the use of active learning by two engineering instructors after attending a faculty development workshop. Although the case study approach limits the generalizability of the findings, this study offers several implications for research focusing on adoption of active learning in engineering classrooms. The findings of this study indicate the influence of the instructors' conceptions of teaching in selection and design of active learning, and subsequent impact of these design choices on student engagement. While researchers have examined faculty conceptions in other disciplines, minimal research has been conducted to study engineering instructors' conceptions. Future studies may focus on examining engineering instructors' conceptions about active learning.

Existing research examining the use of active learning by engineering instructors has primarily relied on instructor self-reports and has minimally examined student resistance to active learning. Student resistance has been identified as a major barrier to the adoption and continued use of active learning. The findings of this study identify the inappropriate design of active learning exercises as a reason behind student resistance. Future work may focus on examining factors relating to the design of active learning exercises that influence student engagement in engineering classrooms. This will help in identifying key aspects of curriculum design that promote student engagement and assist engineering instructors in the use of active learning. Researchers may follow a mixed methods approach with an initial qualitative phase investigating the factors influencing student engagement, followed by a quantitative phase evaluating the design of active learning exercises implemented by instructors across multiple institutions with respect to the identified themes in the first phase.

The choice of case study methodology limits the direct applicability of the findings to other contexts. Contextual factors such as type of institution and level of students might influence the use of active learning. Also, the nature of courses and class size may influence student engagement in active learning. For example, elective courses may receive different response than required courses. Also, courses focusing more on analysis may differ from design courses including freshman and capstone design. Future work may focus on comparing different types of courses (elective versus required, high vs low enrollment and analytical versus design). Replication of similar case studies examining post-workshop use of active learning in other institutions, departments and courses in the future will generate further understanding and identify strategies facilitating effective adoption. Lastly, researchers may also replicate similar case studies to examine other engineering faculty development workshops.

Appendix A – Classroom Observation Protocol

Classroom Observation Form

Please complete this page for **EACH instance of active learning**. Every time the instructor asks students to perform a specific task (talk to your neighbor, work on this problem), please consider that to be a new instance of active learning. Therefore, a complex problem may include several instances of active learning.

1. **Course details.** Name of observer: ____________________

   Course identifier: ____________________

   Date of observation: ____________________

   Class attendance (# students present): ____________________

   Start time of the activity: ____________ End time of the activity: ____________

2. **Information about this active learning instance.**

   Level of difficulty of material. [ ] Difficult [ ] Easy

   Novelty of material. [ ] New [ ] Review

   Describe any cues (if any) the instructor offered on the difficulty or novelty of the problem/material?

3. **Type of active learning.**
   - ☐ Discussion
     - ☐ Group
     - ☐ Individual
   - ☐ Problem Solving Task
     - ☐ Group
     - ☐ Individual
   - ☐ Think-pair-share
   - ☐ Student presentations
   - ☐ Other ____________________

   Comments:

4. **Degree of faculty participation.**
   - ☐ *High participation*: Instructor actively engages students during the exercise, circulating around the room, looking over students work, monitoring student progress, clarifying doubts etc.
   - ☐ *Medium participation*: Instructor only responds to students' questions without monitoring student progress, intervening in their work, etc.
   - ☐ *Low participation*: Instructor does not interact with students during activity.

   Comments:

5. **Instructor introduction of and response during active learning**.	Check if yes	Describe
a. Does the instructor *clearly explain what students are expected to do* and answer questions?		
b. Does the instructor *give students feedback* about their learning?		
c. Does the instructor *solicit student responses* during the activity?		
d. Does the instructor *encourage student engagement* through his/her demeanor?		

e. Does the instructor *use strategies to reduce student resistance*?		
f. Does the instructor *do other things worth noting*?		

6. Student response during active learning.

a. How would you characterize the *level of student engagement* in this class (e.g., what percent of the class exhibits engaged posture, is directly engaged in task, invests high quality time and effort to the activity, and asks insightful questions)?

- ☐ High engagement: More than 90% of class is engaged
- ☐ Mixed engagement: 50% to 90% engaged
- ☐ Low engagement: More than half the class is off-task (i.e., web surfing, texting, chatting, etc.)

b. List the approximate percentage of the class that exhibits the each type of resistance	**Percent**	Describe
Open resistance - voicing objections to activity during class (e.g., "others teachers don't make us do this" or "I don't have time for group work outside of my class schedule")		
Partial compliance - doing the activity very quickly with minimal effort, little to no participation in groups or class discussions, concerns about what the instructor "wants them to do"		
Passive, non-verbal resistance - refusal to participate, pretend to comply, negative body/facial language, chatting about everything but the task in groups		
Other		

7. Did students seem resistant to the activity, and if so, did you observe the instructor doing anything that might have resulted in that resistance?

Classroom Observation Form

*Please complete page for **The First Day of Class***

Course ID (NC/BU/UM, Course: ME438, 1=fall, 2=winter or spring, 3=summer, calendar year): ________________

Instructor: ____

Course Number and Name: ____ Term & Year: _________________

Institution: ________________________________ Date of observation (first day of class): ____________________

Course official start and end time: ________________ Days of week: ______Name of observer: _______________

Course Enrollment: _________________

Describe the classroom layout and seating arrangement

____
____
____

List all of the active learning modes or activities mentioned by the instructor that are to take place during the term

1. ____ _____________________
2. ____
3. ____

How does the instructor introduce active learning?	Check if yes	How if at all did the students react?

Does the instructor **clearly explain what students are expected to do** and answer questions?		
Does the instructor **give students feedback** about their learning or their grade?		
Does the instructor clearly **explain how the new activities will be graded** and how they will affect a student's grade?		
Does the instructor **solicit student feedback**?		
Other		

If there are any instances of Active Learning on First Day of Class, Please Use the other form.

Please attach a copy of the course syllabus to this form.

Appendix B – Additional Faculty Interview Questions

Case Study 1

1) How did you develop the questions for the discussions?
2) Based on your experience, do you think the students fully engage when you ask them to discuss in the classroom?
3) In the survey, I asked the students about the ways in which they responded to the activities and other feedback about the active learning exercises. Overall, the feedback was really positive about active learning. But, some of the students mentioned that they rushed through the activity giving minimal effort. There was also a big majority that talked about something else during the activities. What do you think are reasons why students responded in this way?
4) In the survey, there were a lot of students who found the activities beneficial to their learning. But, there were a major portion of the students who reported that they did not find the activities beneficial. Can you think of any changes you can do to make them more beneficial for the students?
5) In the focus groups, some of the students mentioned that they really liked the activities but they felt that the questions were sometimes really broad and open ended that they could not discuss. Do you agree with that?
6) Throughout the course you always emphasized on the importance of working on problems to be successful in the course. What do you think about doing problem solving as active learning in the classroom?
7) What challenges other instructors might face when they start using active learning?
8) In the semester, you usually used group based discussions. But, towards the end of the semester you had a group based problem solving exercise. The students were highly engaged in the activity and in the focus groups students provided positive feedback about the activity. What are your thoughts?

Case Study 2

1) When did you attend NETI 1 and NETI – Advanced? What made you attend the second workshop?
2) How was NETI 1 different from NETI 2?
3) How did you design the projects for the course?
4) You granted extension to first and last project. How were they different from the other two?
5) There was less interaction between students for the second and third projects? Why do you think this happened?
6) During the hands on session, in one of the class sessions, you asked students to work on a sample problem. There was low engagement initially during the activity. Why do you think that happened?
7) How did you select the readings?
8) Most of the readings were journal articles and there were few white papers. What in your opinion is better for student engagement in the discussions?
9) Were the readings relevant to the homework?
10) In one of the class sessions, you did a discussion based on a problem solving exercise. High engagement was received for that activity. How did you design that activity?
11) What aspects did you consider in designing the presentation activities?
12) High engagement was received when presenting students asked questions to the audience. What are your thoughts about this observation?
13) What do you think can be added to or changed to the workshop to help new faculty who are doing active learning?
14) Was there anything in particular in NETI- Advanced that you think should be included in NETI 1?
15) How do you do active learning in your larger classes? How do you design activities? What things do you keep in mind while selecting the questions?

Appendix C – Student Survey

Your Project ID number **(**last four digits of phone #, birth month, birth day**)**: ___ ___ ___ ___ ___ ___ ___ ___

End-of-Term Student Survey

1. In this course, when the instructor asked you to do an in-class activity (e.g., solve problems in a group during class or discuss concepts with classmates), **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)
a. I disliked the activity and voiced my objections.	1	2	3	4	5
b. I focused on doing specifically what the instructor asked, rather than on mastering the concepts.	1	2	3	4	5
c. I rushed through the activity, giving minimal effort.	1	2	3	4	5
d. I felt positively towards the instructor/class.	1	2	3	4	5
e. I tried my hardest to do a good job.	1	2	3	4	5
f. I distracted my peers during the activity.	1	2	3	4	5
g. I pretended but did not actually participate.	1	2	3	4	5
h. I felt the effort it took to do the activity was worthwhile.	1	2	3	4	5
i. I participated actively (or attempted to).	1	2	3	4	5
j. I talked with classmates about other topics besides the activity.	1	2	3	4	5
k. I felt the instructor had my best interests in mind.	1	2	3	4	5
l. I saw the value in the activity.	1	2	3	4	5
m. I felt the time used for the activity was beneficial.	1	2	3	4	5
n. I enjoyed the activity.	1	2	3	4	5
o. I surfed the internet, checked social media, or did something else instead of doing the activity.	1	2	3	4	5

2. In this course, when the instructor asked you to do an in-class activity (e.g,. solve problems in a group during class or discuss concepts with classmates), **how often did the instructor do the following things**?	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)
a. Clearly explained what I was expected to do for the activity.	1	2	3	4	5
b. Clearly explained the purpose of the activity.	1	2	3	4	5
c. Discussed how this activity related to my learning.	1	2	3	4	5
d. Solicited my feedback or that of other students about the activity.	1	2	3	4	5
e. Used activities that were the right difficulty level (not too easy, not too difficult).	1	2	3	4	5
f. Walked around the room to assist me or my group with the activity, if needed.	1	2	3	4	5
g. Encouraged students to engage with the activity through his/her demeanor.	1	2	3	4	5
h. Gave me an appropriate amount of time to engage with the activity.	1	2	3	4	5

3. Please rate your level of agreement with the following items.

	1. Strongly disagree	2. Disagree	3. Neutral	4. Agree	5. Strongly agree
a. Overall, this was an excellent course.	1	2	3	4	5
b. Overall, the instructor was an excellent teacher.	1	2	3	4	5

4. What final grade do you expect to receive in this course? F D- D D+ C- C C+ B- B B+ A- A A+

5. For each of the following things, please indicate how often you did each thing **in this course** and how often you would like to do each **in your ideal course**.

	In this course, how often did you …… 1. Never	2. Seldom (1-5 times/semester)	3. Sometimes (5-10 times/semester)	4. Often (once a week)	5. Very often (more than once/week)	**In your ideal course**, how often would you like to …… 1. Much less	2. Slightly less	3. About the same	4. Slightly more	5. Much more
a. Listen to the instructor lecture during class.	1	2	3	4	5	1	2	3	4	5
b. Brainstorm different possible solutions to a given problem	1	2	3	4	5	1	2	3	4	5
c. Find additional information not provided by the instructor to complete assignments	1	2	3	4	5	1	2	3	4	5
d. Work in assigned groups to complete homework or other projects	1	2	3	4	5	1	2	3	4	5
e. Make individual presentations to the class	1	2	3	4	5	1	2	3	4	5
f. Be graded on my class participation.	1	2	3	4	5	1	2	3	4	5
g. Study course content with classmates outside of class.	1	2	3	4	5	1	2	3	4	5
h. Assume responsibility for learning material on my own.	1	2	3	4	5	1	2	3	4	5
i. Discuss concepts with classmates during class.	1	2	3	4	5	1	2	3	4	5
j. Make and justify assumptions when not enough information is provided.	1	2	3	4	5	1	2	3	4	5
k. Get most of the information needed to solve the homework directly from the instructor	1	2	3	4	5	1	2	3	4	5
l. Be graded based on the performance of my group.	1	2	3	4	5	1	2	3	4	5
m. Preview concepts before class by reading, watching videos, etc.	1	2	3	4	5	1	2	3	4	5
n. Solve problems in a group during class.	1	2	3	4	5	1	2	3	4	5
o. Solve problems individually during class.	1	2	3	4	5	1	2	3	4	5
p. Answer questions posed by the instructor during class.	1	2	3	4	5	1	2	3	4	5
q. Ask the instructor questions during class.	1	2	3	4	5	1	2	3	4	5
r. Take initiative for identifying what I need to know.	1	2	3	4	5	1	2	3	4	5
s. Watch the instructor demonstrate how to solve problems.	1	2	3	4	5	1	2	3	4	5
t. Solve problems that have more than one correct answer.	1	2	3	4	5	1	2	3	4	5
u. Do hands-on group activities during class.	1	2	3	4	5	1	2	3	4	5

Appendix D – Additional Student Focus Group Questions

Case Study 1

1) In the feedback poll, some of the students asked the instructor for more examples. Do you all wanted the same?
2) There was drop in attendance after the first exam. Why do you think the students stopped coming to lectures?
3) In last week lecture, students did not show excitement towards active learning. But, in the same session, instructor asked this circuit question and without being assigned as active learning, most of the student participated. Why do you think this happened?

Case Study 2

1) In the hands on lab sessions, would you prefer activities in addition to the demonstrations?
2) In one of the sessions, you were asked to fill a table in addition to the following along the demonstrated steps. There was low engagement. Why do you think that happened?
3) There was more interaction between groups for the first and last project. Any reasons come to your mind when you think of that?
4) What are your opinions about the presentations? Do you find them useful?
5) Project presentations had more discussions than case studies. What were the reasons behind low engagement?
6) In presentations, when the presenting students posed questions to the audience, there was high participation. What in your opinion led to high engagement in the audience?
7) What are your thoughts about the discussions based on readings? Did you like them?
8) There was high engagement when the assigned reading was a white paper. Why do you think that happened?

Appendix E – NETI Workshop Content

[The workshop content was reproduced from Table of Contents of the NETI Workshop manuals provided by one of the study participants for NETI 1 and workshop convener for NETI 2]

NETI 1

Key Questions	**Topics Covered**
How do students learn? How do I learn? What can I do to reach students whose learning styles are different from mine?	Learning styles Resources on learning styles
How do I plan a course? What do I do in the first week?	Learning objectives and Bloom's Taxonomy Writing objectives Preparing course syllabus Addressing ABET outcomes Resources on course design and developing higher-level thinking skills
How can I assess learning reliably and fairly? How can I use formative assessment to improve both learning and teaching? How can I be both rigorous and fair in evaluating outcomes (grading)?	Assessment and evaluation of learning Designing tests and grading Diagnostic assessment Formative assessment Course grading Resources on assessment of learning
How can I be an effective lecturer and get students actively involved in class?	What to do during the first week Lecturing tips Active learning techniques Strategies for engagement Resources on lecturing and active learning
How can I teach students to work effectively in teams?	Cooperative learning Assessing team member effectiveness Resources on cooperative learning

What is inductive teaching? What are the most common inductive teaching methods, how do they differ, and what does research say about their effectiveness?	Inductive teaching and learning Inductive instructional methods Inquiry-based learning and problem-based learning Resources on inductive teaching and learning
What student issues am I likely to confront? What problem students am I likely to face? What do I do about them?	Crisis clinic Cheating Resources on advising Gender and engineering education
How can new faculty members get off to a good start?	Success strategies for new faculty Time management Additional resources on new faculty members
How can I improve the quality of engineering instruction on my home campus?	Engineering faculty development Motivation of adult learners Teaching workshops

NETI 2

Key Questions	**Topics Covered**
Setting goals	Learning objectives and Bloom's Taxonomy ABET process Illustrative learning objectives Instructional methods
Why do students have such a hard time understanding important concepts? What is inductive teaching, and how can it help students develop conceptual understanding?	Promoting and assessing conceptual understanding Inductive teaching methods Inquiry-based instruction
What is cooperative learning? What does research say about its effectiveness? What can go wrong when you do it, and how can you make sure it doesn't?	Cooperative learning Forming teams Assessing individual performance for group work Dealing with student resistance Methods that address ABET outcomes
What is problem-based learning? How does it differ from other inductive methods? What are its benefits and pitfalls, and how can the pitfalls be avoided?	Problem-based learning – Definitions, comparisons and research base Implementing problem-based learning Developing PBL assignment Grading rubric for PBL assignment Student resistance

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