A STUDY OF THE PEDAGOGICAL STRATEGIES USED IN SUPPORT OF STUDENTS WITH LEARNING DISABILITIES AND ATTITUDES HELD BY ENGINEERING FACULTY

by

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DEDICATION

This study is dedicated to the students with learning disabilities who are interested in pursuing an education in engineering.

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ABSTRACT

This study used an anonymous online survey instrument to explore the educational preparation as well as the pedagogical and assessment methods used in support of students with learning disabilities (LD) by engineering faculty members from undergraduate engineering programs of four southern California educational institutions. This work also sought to determine whether engineering faculty members utilized pedagogy that encouraged student development of metacognitive skills. Further, engineering faculty attitudes toward students with LD and faculty willingness to provide accommodations for students with LD were examined through the survey instrument. Although participant responses (n=30) offered evidence of positive attitudes and willingness to support students with LD, results indicated that more faculty development regarding the needs of students with LD and of alternative pedagogical and assessment methods was warranted for college-level engineering faculty.

CHAPTER 1

The juxtaposition of the U.S. President's call for improving science education (Mervis, 2010) and the 2009 report from the U.S. Department of Education that 11% of students in higher education display some disability emphasizes the importance of making the sciences more accessible to students with learning disabilities (LD) as well as to those without learning disabilities. The educational goal that the U.S. population exhibit science literacy in order to participate in the developing global society that emphasizes sciences and technology (Duschl, 2008) means that college-level students with LD, representing the largest population of entering college freshmen with some disability (Trainin & Swanson, 2008), cannot be ignored in science education. With improved procedures to diagnose learning disabilities an increasing percentage of students with LD are currently found in student bodies (Grumbine & Alden, 2006), although students with LD are still reported to be entering college at lower levels than their non-LD classmates (Sparks & Lovett, 2009). Nevertheless, students with LD represent a growing percentage of students in the science classroom and the downward trend in science and mathematics achievement in the United States (Calhoun, 2003; Vannest, Mason, Brown, Dyer, Maney, & Adiguzel, 2009) as well as the reduced persistence to degree attainment (Hadley, 2007) are growing concerns for this country to compete successfully in the developing global environment.

Background of Problem

Section 504 of the Rehabilitation Act of 1973 as well as the Americans with Disabilities Act of 1990 requires nondiscrimination toward students with any disabilities

by colleges and other institutions of higher education. The laws further require equal access to academic content for all students. While college-level instructors are required to provide this equal access, the law does not specify the details for these provisions. Wide variation exists among faculty, courses, and institutions regarding how accessible course content is for all students (Scott & Gregg, 2000).

Additional evidence exists that supports the need for addressing science, mathematics, and engineering access for students with LD. For example, reduced access to and/or a lack of interest in the sciences for students with LD was reflected in the report that only six percent of the students with learning disabilities will become scientists or engineers (Scruggs, 2004). This concern was reiterated by Hedrick, Dizén, Collins, Evans, and Grayson (2010) when they reported that 15% of scientists between 65 and 75 years of age have learning disabilities, while only seven percent of scientists under the age of 35 years possess learning disabilities. A decline in student interest and retention in engineering programs for the last two decades (Ferrini-Mundy & Güçler, 2009; Wulf & Fisher, 2002) provided one result of the poorer learning environment in which strategies used in the classroom have not served student learning (Baldwin, 2009). The decline was so severe in engineering that Chowdhury (2004) reported that as many as 50% of engineering students do not obtain their college degrees.

The reduction of interest and retention has been particularly significant for female and underrepresented minority students, but students with LD were not addressed (Amenkhienan & Kogan, 2004; Wulf & Fisher, 2002). These data point to a need for focus on greater access to sciences for diverse students, including students with LD and

for the cultivation of greater interest in sciences, technology, engineering, and mathematical (STEM) disciplines among all students. Faculty at the college level in many disciplines, including the sciences, mathematics, and engineering are not required to have participated in coursework specific to education, such as pedagogical methods or learning processes (Baldwin, 2009). While they may be experts in their fields of study, faculty in the sciences, mathematics, and engineering may lack the knowledge to provide instruction that serves a diverse population of students, including students with LD.

Students with Learning Disabilities. A few authors have attempted to define or identify the characteristics and abilities of the population of college students recognized to have learning disabilities. For example, Sparks and Lovett (2009) analyzed the results of empirical studies that compared students with LD to students without LD in an effort to generalize about college-level students with LD. These authors found that, as a group, students with LD enroll in college less often than students without LD. In addition, students with LD had less frequently participated in college preparatory courses in high school. However, the average academic performance for students with LD fell within the average range for all students and, in fact, cognitive ability levels of students with LD in this study were slightly higher than cognitive levels for students without LD.

Another study by Heiman and Precel (2003) found that there was no difference in grade point average for student with LD compared to students without LD. Students with LD in this study reported higher anxiety levels and greater difficulties in handling demands related to academic responsibilities. However, in this study neither group of students had greater difficulty with mathematics. The disciplines emphasizing language

skills, such as social sciences and humanities were experienced as more difficult for students with LD. In addition, students with LD utilized more oral and visual study approaches.

Few researchers have specifically examined the population of students with LD in the STEM disciplines. Melber and Brown (2008), however, examined the methods science instructors could use for improving accessibility to science curricula for students with LD. Their review addressed high school students, but their recommendations could apply to undergraduate students as well. The authors emphasized, for example, the use if multiple methods of student assessment to allow students the opportunities to use their strengths in demonstrating their learning. Melber and Brown also encouraged the use of objects, specimens, and field work to increase enthusiasm and to provide a context for course content. In addition, student motivation was expected to improve. These suggestions offer a connection to the findings by Heiman and Precel (2003) that study strategies used by students with LD incorporate more of their senses through visual and auditory methods.

Even the limited research and analysis available demonstrates that the college student with LD has abilities comparable to other students and is capable of success in these disciplines. Mechanisms for providing the context and concrete experiences with science content for students with LD serve learning for a diverse population of students. The use of multiple assessment methods serves a diverse student group, including students with LD.

History of Engineering Education Reform. Conversations regarding engineering education reform started during the 1980's and became prevalent during the 1990's (Ferrini-Mundy & Güçler, 2009). Reform efforts for engineering education began in earnest, perhaps, with the Engineering Foundation Conference in 1998, entitled *Realizing the New Paradigm for Engineering Education* (Splitt, 2003). The new paradigm continued to require that students acquire a strong background in the sciences and mathematics, as had been considered foundational for engineering education for the previous 50 years (Dym, Agogino, Eris, Frey, & Leifer, 2005; Wulf & Fisher, 2002), but it incorporated development of additional academic and personal skills to improve an engineering student's likelihood of professional success. The new engineering education model incorporated the integration of academic disciplines, development of communication and teamwork skills, and it stressed inquiry-based or problem-based learning (Dym et al., 2005; Splitt, 2003) and was supported by the National Science Foundation development of the Engineering Education Coalition (EEC), composed of 44 universities, institutes, and one community college district with engineering programs (Borrego, 2007). While under the older paradigm fewer students were completing their degrees and levels of completion were very low for female and ethnic minority students (Fromm, 2003; Wulf & Fisher, 2002), development of the EEC supported an effort "to stimulate bold, innovation, and comprehensive models for systemic reform" (www.foundationcoalition.org/home) in engineering programs.

The need to improve pedagogy and curriculum design acknowledged in the literature (Dym et al., 2005; Fromm, 2003; Froyd & Oiland, 2005) led to reported

successes toward improving engineering education (Fromm, 2003; Splitt, 2003). For example, in support of pedagogical reform, the National Academy of Engineering began honoring high quality engineering instructors with the Bernard M. Gordon Prize for the Enhanced Educational Experience for Engineers in 2003. In addition, some engineering schools have begun providing cross-disciplinary curricula in engineering programs with successful retention results across ethnic and gender groups (Fromm, 2003). Nevertheless, the majority of engineering programs continued to use traditional pedagogical methods (Ferrini-Mundy & Güçler, 2009) and many programs in which alternative curricula or pedagogy were begun demonstrate struggles to meet the new standards (Borrego, 2007). Often faculty support has waned due to institutional pressures to focus on research (Akerson et al., 2002). The emphasis on faculty research rather than teaching for most educational institutions with engineering programs has meant the effort necessary to maintain teaching reforms has been difficult to sustain (Baldwin, 2009).

Statement of Problem

Flick, Sadri, Morrell, Wainwright, and Schepige (2009) reported the well-established concerns that college students of all backgrounds have not been receiving quality mathematics and science teaching. These authors reported that it may be complaints of teaching quality that motivate students to discontinue effort toward science and mathematics majors in college, and possibly toward completion of the college degree.

Faculty from STEM disciplines believe in the process of science and empirical study. Much of the content presented in the courses offered by faculty from these

disciplines arose from studies conducted by researchers in these disciplines. Faculty from STEM disciplines hold empirical research in high regard (Fairweather, 2008). However, research indicates that many faculty in these disciplines are not acknowledging or are unaware of the evidence supporting the need for pedagogy that provides improved access to all students, including those with learning disabilities.

After examination of empirical studies published between 1990 and 2008 regarding students with LD at the college level, Sparks and Lovett (2009) ascertained that only 2000 students with learning disabilities had been included in the research. These authors pointed out that this is a fraction of students in this country with LD. Of further concern is that, while an occasional engineering student is part of a study regarding students with LD (e.g., Hadley, 2007), students with LD are essentially absent from research of engineering education. This lack of engineering student research participants points to the need for research that considers the educational environment in engineering for students with LD.

Purpose of Study

The fundamental question of this study asks what is the current pedagogical knowledge held by college engineering faculty and following this, what pedagogical and assessment approaches are practiced in college-level engineering courses. In support of these research questions the study seeks to determine the attitudes held by engineering faculty toward students with LD and how engaged these faculty are in improving course content access to students with LD and whether faculty make effort to incorporate pedagogical approaches that aid student development of metacognitive strategies.

Research questions

1. What educational backgrounds do engineering faculty members have that provide them knowledge of learning theory and pedagogical research? Have engineering faculty taken education courses?

2. What pedagogical and assessment approaches do engineering faculty members use in college-level engineering courses?

3. What teaching strategies that assist student development of metacognitive skills do college-level engineering faculty members incorporate into their teaching?

4. (a) What are the attitudes of engineering faculty toward students with LD? (b) What are the attitudes of engineering faculty for providing accommodations for students with LD?

5. What willingness to try new pedagogical approaches to improve learning for all students, including students with LD is demonstrated by engineering faculty members?

Importance of Study

Efforts to improve pedagogical practices in STEM disciplines have occurred inconsistently by institutions and individuals with the interest of improved instruction for the growingly diverse college-level student body. There exists a continued need to determine the level of preparedness held by current college faculty for alternative instructional approaches to traditional instruction commonly used by most STEM faculty. By investigating pedagogical knowledge and current pedagogical practices of college faculty in engineering, evidence may be gathered supporting the need for more or less professional development for engineering faculty members.

Theoretical Contexts

Conceptual change theory. The conceptual change theory centers on the change of one's current concepts when those concepts are challenged by a new experience or new information (Posner, Strike, Hewson, & Gertzog, 1982). Conceptual change is highly relevant to science learning in the STEM disciplines. In this study, however, the theory is also applied to the change in faculty concepts of ability of students with LD in the college engineering classroom.

Science educators and research scientists, mathematicians, and engineers, who teach at the college level, study and believe in the scientific process, including observations upon which empirical study is built (Fairweather, 2008). Many of the concepts the STEM faculty possess regarding students with LD likely reflect their observations as well as their beliefs. A fundamental principle of this study rests on the premise that conceptual change for faculty members would occur if the faculty were aware of the results of educational and pedagogical research in support of the abilities of students with LD in the STEM classroom.

Cognitive load theory. Within this study references are made to the cognitive load theory. This theory addresses the interaction of a learner's limited working memory (WM) with the essentially unlimited long-term memory (Paas, van Gog, & Sweller, 2010). Instructional design is concerned with overloading the learner's WM with the cognitive elements identified by this theory and described by Paas et al. as intrinsic, extraneous, and germane cognitive load. Intrinsic cognitive load reflects complexity of content; extraneous cognitive load refers to complicating elements that are unnecessary

for learning some particular content; germane cognitive load reflects the working memory needed for processing intrinsic load and developing what these authors called schema, or mental models of the learned content. Some students with LD exhibit deficits in WM resources (Brinckerhoff, McGuire, & Shaw, 2002), so recognition of instructional methods that reduce cognitive load may be particularly important for these students.

Definition of Terms

Constructivism. The term constructivism is used intermittently in this study in relation to teaching strategies and resulting student learning. Constructivist learning is typically equated with unstructured, problem-based learning (Kirschner, Sweller, & Clark, 2006; Schmidt, Loyens, van Gog, & Paas, 2007) and is considered by some to result in a learner's cognitive overload and the potential for development of misconceptions (Kirschner et al., 2006). Problem-based, task-centered, active, and experiential learning are called constructivist learning approaches by some authors, but may not be considered as minimally guided as Kirschner et al. (2006) indicated (Schmidt et al., 2007). The work of these authors demonstrates the controversy surrounding the use of constructivist teaching strategies, as opposed to the teacher-controlled instructivist teaching strategies. As described in Chapter 2 of this study, learning and achievement are often improved for students with LD by the more active learning approaches; cognitive overload is, nevertheless, a concern for many of these researchers (e.g., Grumbine, Hecker, & Littlefield, 2005; Hadley, 2007).

Learning disability. The definition of learning disabilities used in this study aligns with the definition developed by the National Joint Committee on Learning

Disabilities (NJCLD) that incorporates elements appropriate for adult students (Brinckerhoff et al., 2002). This definition, that takes into account various sources of learning disabilities, such as dysfunction of the central nervous system (CNS) or from information-processing problems that may express themselves in executive functioning, cognitive processing, or the learner's general information knowledge base, serves as the working definition for this study. This definition of learning disabilities recognizes a "heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning, or mathematical abilities" (Brinckerhoff et al., 2002, p. 113).

Although individual learning disabilities or attention-deficit/hyperactivity disorder (ADHD) may be specifically addressed in this study and in the literature, for many students more than one of these conditions is present (Brinckerhoff et al., 2002; Grumbine & Alden, 2006). Therefore, this study utilizes the definition of learning disabilities that incorporates all of the specific identifiable learning diagnoses as demonstrated by Grumbine and Alden (2006).

Metacognition. Metacognition and metacognitive skills in this study refer to a student's knowledge of how he or she learns, including knowledge of what strategies the student uses to learn effectively. Metacognition is often reported to align with a student's self-efficacy (Hall & Webster, 2008), the premise of which this study also uses.

Universal Design for Learning. The principle of universal design was originally founded in architecture in an effort to make physical environments accessible to all people with or without any form of disability (Scott, McGuire, Shaw, 2004). The use of

this term in an educational setting not only reflects accessibility to the physical setting for student learning, but includes accessibility to academic content for all students. The term used in this study refers to the principles articulated by Grumbine, Hecker, and Littlefield (2005) of multiple means of presenting content, multiple methods for student demonstration of knowledge, and multiple methods of student engagement.

CHAPTER 2: LITERATURE REVIEW

Faculty from the sciences, mathematics, and engineering (STEM) disciplines use a variety of pedagogical methods for teaching the content of their courses. It is not clear, however, what pedagogical knowledge, understanding, and attitudes relevant for students with learning disabilities (LD) are brought to the classroom by these faculty. A review of the knowledge and skills necessary for learning in these disciplines, the challenges faced by students with LD in the STEM classroom, and the pedagogical approaches faculty use provide the framework for examining faculty knowledge of abilities and needs of the student with LD. In addition, this review includes examination of faculty attitudes toward students with LD as well as the theoretical bases for the pedagogy approaches the faculty use.

The expectation is that many faculty from the STEM disciplines bring misconceptions about students with LD to their teaching. With a focus on faculty from the engineering disciplines, it is the conceptual change theory, which provides a method for one's concept to change when challenged by new information, that creates the framework for studying the pedagogical knowledge and attitudes possessed by faculty. There is an additional focus on faculty encouragement of student development of metacognitive skills, in response to research indicating how important these skills are for academic success of the student with LD.

Knowledge and Skills Required for Success STEM Disciplines

Science encourages development of thought and imagination toward seeking explanations for what is observed in the natural world and can be important in the

educational development for students with LD (Scruggs & Mastropieri, 2007). Science was seen as an expression of a holistic relationship that incorporated the student, the student's relationships with others, and the relationship to the natural world (Kozoll & Osborne, 2004). As indicated by research from Ryan (1994) regarding first-year college students' life adjustments, students with LD have a tendency to remain dependent on their families and avoid independence. Through the sciences, a student could develop the capability to understand life issues from the student's personal and social arenas and to act more independently and appropriately to assure the health and well-being of that student (Ahlgrim-Delzell, Knight, & Jimenez, 2009).

This review section begins by examining conceptual knowledge that has been determined to be fundamental to learning in the sciences (Michael, 2006). Procedural and strategic knowledge, shown to be particularly important for learning in the engineering disciplines (Chowdhury, 2004), are addressed. Further, learning concerns specific to students with LD are examined as are the misconceptions commonly reported to be brought to the classroom (Modell, Michael, & Wenderoth, 2005). Finally, as a result of the reported importance of metacognitive skills for student learning (Chowdhury, 2004; Hall & Webster, 2008), the review concludes with an examination of the knowledge and skills needed for student learning in STEM disciplines.

Conceptual Knowledge

According to Michael (2006), development of declarative knowledge as well as conceptual knowledge emphasized in science learning typically required memorization. In many of the sciences, such factual knowledge often could not, however, be separated

from the needed conceptual base required for comprehension of discipline-related definitions, according to Michael. In their review of education reforms of college sciences, mathematics, and engineering, Ferrini-Mundy and Güçler, (2009) articulated the importance of conceptual understanding also for mathematics and physics, disciplines that are fundamental to engineering. Development of conceptual knowledge, therefore, must be considered important for science learning.

Reform efforts to move away from the emphasis on procedural knowledge toward development of conceptual knowledge within college-level calculus courses were widespread from the 1980's into the 1990's (Ferrini-Mundy & Güçler, 2009). While the report by Ferrini-Mundy and Güçler indicated that all of the reform efforts did not succeed, the focus on conceptual knowledge continued to be considered fundamental to calculus instruction to the current time.

Procedural and Strategic Knowledge

Procedural knowledge encompasses the knowledge of the steps necessary for accomplishing a task as well as the knowledge needed to judge when those steps are appropriately applied (Anderson & Krathwohl, 2001). Examples offered by Anderson and Krathwohl demonstrate that procudrual knowledge is usually domain-specific, such as knowledge of the algorithms used to solve algebraic problems or the steps necessary for problem-solving in the sciences. Procedural knowledge is an important element of knowledge needed in engineering design for solving problems.

Development of students' procedural knowledge skills was a major focus of the project-based learning teaching design described by Dym et al. (2005), increasingly used

in engineering programs. Chowdhury (2004) identified procedural knowledge as an application of the conceptual knowledge used in solving problems in his pedagogical design for an introductory engineering course about electrical power. With an emphasis on science education reform, Duggan and Gott (2002) examined the science knowledge skills needed for work and life situations once students leave school. These authors also recognized that conceptual knowledge was important, but they identified the significance of procedural knowledge for evaluation of scientific evidence in work and life.

Learning in the STEM Disciplines for Postsecondary Students with LD

While skill deficits exhibited by students with LD vary within each individual student, Grumbine and Alden (2006) emphasized that difficulties with organization, reading, writing, memory, vocabulary development, and note-taking were common deficits for these students in science classes. Peers without LD, enlisted to take notes during class, were frequently an essential requirement for students with LD in college according to Hadley (2007), a reflection of the fact that lectures were presented too quickly for these students. As Calhoun (2003) put it, the manner in which science classes are presented currently favors "sprinters over long-distance runners" (p. 77), making success in the sciences more difficult for many students with LD who may require more time to process course content (Brinckerhoff et al., 2002). In addition, Hadley (2007) pointed out that students with LD often have a reduced ability to determine the major points within a lecture, adding to their note-taking difficulty. Moin, Magiera, and Zigmond (2009) supported Hadley's contentions when they offered suggestions for faculty that deemphasized language or verbal memory skills, abilities about which

students with LD are often weak. Furthermore, tasks that depended on insight from a student or from his or her ability to construct knowledge formally were difficult for some students with learning disabilities, according to Scruggs and Mastropieri (2007), but in their review of their own work on science education, particularly for students with special needs, these authors also showed that these students could increase their learning by drawing conclusions when lessons were highly structured by educators.

Although research repeatedly demonstrated that students with LD were fundamentally equally capable of academic success as were their non-LD peers (e.g., Hedrick et al., 2010; Heiman & Precel, 2003; Sparks & Lovett, 2009), instructors continued to expect students with LD to demonstrate difficulties in academic tasks and to learn and achieve less than the non-LD students (Ahluwalia, 2009; Scott & Gregg, 2000). In addition, some faculty reportedly believed that students who received accommodations gained an unfair advantage over non-LD students (Casey, 2007).

Calhoun (2003) identified major barriers to successful student achievement in the sciences. All of these barriers could also apply to a student with learning disabilities. Acclimation to the campus, including science classrooms or labs, a mismatch between learning style and teaching style of science faculty, and an absence of role models representing the diversity of students were all considered by Calhoun (2003) to be challenging obstacles to student success. According to Grumbine and Alden (2006), the skills needed for the students with LD to be successful in the sciences, such as time management, planning, and persistence on tasks, are needed for most students to succeed in the sciences. Scruggs & Mastropieri (2007) reported, in fact, that the extensive

vocabulary associated with studying the sciences surpassed the recommended vocabulary terms in a foreign language course. The task of learning this extensive and complex vocabulary could increase cognitive load in working memory especially for many student with LD, including students with attention-deficit/hyperactivity disorder (ADHD) (Huang-Pollock & Karalunas, 2010).

Huang-Pollock and Karalunas (2010) compared two student groups with ADHD who exhibited inattention and deficits in inhibitory control with a group of students without ADHD in order to determine the effect of working memory (WM) on acquisition of cognitive skills. The authors demonstrated that WM requirements affected both groups of students with ADHD, leading to slower processing as well as a reduction of skill acquisition on the complex cognitive tasks used in the study. The authors acknowledged that there are inconsistencies across the literature for identification of ADHD categories, however, even though the students in this study were younger children, the principle of increased demand on a student's WM in acquiring skills associated with complex tasks, such as those in STEM classrooms, likely applies to college students with ADHD as well.

Hadley (2007) used qualitative research to glean the experiences and perceptions of first-year college students with LD from diverse disciplines, including sciences and engineering, in relation to student reading skills. By using a variety of types of evidence, such as student notes, self-management tools, course success, faculty comments, and student interviews, she examined students' success in developing college-level writing ability, their comfort in the classroom, including during exams, and their cultivation of

autonomy in the college context. Although the sample arose from a single institution and incorporated only ten students, for those students it was clear that institutional support and course accommodations were recognized to be very necessary. Hadley quoted an engineering student who felt that he would not pass his classes if he were not receiving accommodations, such as extended time on exams and note-taking assistance, supporting the necessity that faculty understand the abilities and needs for students with LD.

McGlaughlin, Knoop, and Holliday (2005) compared college students with LD and those with no diagnosis in order to discover specific deficits affecting student ability to succeed in algebra courses. Their results indicated that college students with math-related LD display weakness in working memory, reading comprehension, and nonverbal reasoning skills. In addition, these students' math fluency scores, reportedly related to working memory, were low. The affect of factors, such as depression, high or low anxiety, and inattention for college students with and without LD on math fluency, disclosed by these authors, further demonstrated that it is necessary for faculty to have well-informed knowledge regarding all students, including those students with LD.

Misconceptions

Conceptual errors held by students regarding scientific or mathematical content, called misconceptions, have been widely studied since the 1980's (Carey, 1986). The pervasiveness of science and mathematics misconceptions and the difficulty with which these erroneous mental models are eliminated has led to specific research focus on this topic by many authors (e.g., Leviatan, 2008; Lynch, Taymans, Watson, Ochsendorf, Pyke et al., 2007; Modell et al., 2005). Several terms have been used in an effort to express

variability of the source of the misconception (Modell et al., 2005). According to Modell et al., when a student's misconception arose from his or her experience related to the topic in the real world, use of the term misconception was appropriate. Misconceptions that arose, however, without any previous experience related to the particular topic or as a result of the student's effort to create an explanation for accumulated natural world experiences were called preconceptions, naïve beliefs, or alternative conceptions by various authors. The present study followed the beliefs of Modell et al. in considering the variation in terminology as source of confusion, rather than clarity and, therefore, used only the term, misconception.

Misconceptions may arise from a variety of sources encompassing personal misinterpretations of language, misunderstandings of phenomena from other disciplines, errors from texts and past schooling as well as an instructor's misconceptions (Modell et al., 2005). Student misconceptions brought to the learning environment from any source were recognized by Modell et al. to be so fundamental to a student's mental model of a subject that only the student could correct the misconceptions with the instructor serving only as a facilitator for the process.

The recognition that the instructor can only facilitate the conceptual change necessary to eliminate student misconceptions explained why Sundberg (2003) incriminated what was termed the traditional passive lecture format, which is widely used in teaching college-level sciences and engineering (DiCarlo, 2009; Sandoval & Reiser, 2004), as an unsuccessful method of overcoming prior student misconceptions. These authors offered evidence for Wieman's (2007) assessment that the traditional lecture was

not a successful method for most students to master concepts. Upon discovering student misconceptions, faculty members would have an opportunity to design course activities that helped students rebuild their conceptions about course content (Modell et al., 2005), rather than rely on the familiarity of the traditional lecture instructional approach. Although the report by Lynch et al. (2007), comparing the application of a guided inquiry chemical curriculum to demographically matched student groups, applied to middle school, its results supported the recognition that students' conceptual changes were necessary to lessen misconceptions. Therefore, pedagogical strategies that support conceptual change are necessary to support student learning.

Leviatan (2008) promoted a questionnaire-based instruction method to aid instructors' recognition of mathematics misconceptions. This instructional method, in addition, applied well to diagnosing student weaknesses in transitioning from one mathematics course, such as precalculus to the sequential course, calculus I. Modell et al. (2005) stressed that the complexity of the course content could lead to misconceptions, so instructor recognition of students' misconceptions provided the opportunity to assist the student toward conceptual change and learning. It has been shown that effort must be made by faculty, however, to increase their awareness of students' misconceptions (Leviatan, 2008), which must factor into the pedagogical strategies chosen.

Metacognitive Skills for Learning in the Sciences and Mathematics

The definition of metacognition varied slightly from author to author, but could generally be summarized as an individual's self-awareness and self-management of knowledge and awareness combined with the behavioral adjustment necessary to control

and regulate one's cognitive processes toward learning (Anderson, Thomas, & Nashon, 2009; Koch, 2001; Trainin & Swanson, 2005; Yürük, 2007). In addition to self-awareness and monitoring of one's cognitive processes in order to learn strategies and use those strategies effectively toward learning (Volet, Vauras, & Salonen, 2009), the feedback one provided to oneself from cognitive processing also led to self-regulation. Self-regulation and motivation to apply strategies was assessed by Borkowski (1992) to be significant for understanding the learning processes of students with LD. Borkowski found that the student's feelings of self-efficacy were a consequence of the motivation to utilize learning strategies. Since that research, other authors have recognized that self-efficacy for self-regulatory processes reinforced self-regulation (Hall & Webster, 2008: Usher & Pajares, 2008). In their validity study Usher and Pajares (2008) reported that student self-efficacy positively correlated with academic self-efficacy, valuing school, and success in academic tasks, such as writing essays, solving mathematics problems, and science competence. Although Hall and Webster (2008) did not include students with engineering majors, these authors compared academic performance from students with and without LD in an empirical study and found, however, that regardless of academic success, students with LD showed significantly less self-efficacy than their peers without LD.

Student development of metacognitive skills to support academic success was recognized as an important element of engineering education reform by Chowdhury (2004). This author incorporated knowledge of learning styles and a taxonomy of cognitive domains into his development of the initial power-related engineering course in

which a student would enroll. His work took into account that most of the sample of one thousand engineering students learned by doing, as compared to those who learned by logical thinking, for example. The author used this information in order to design pedagogy that would emphasize the hands-on learning style, but would also include the needs of students with other learning styles. A particularly important consideration in his course design was student development of metacognition within the engineering domain.

In applying procedures for development of metacognition within engineering, Chowdhury (2004) incorporated steps that began with an examination of the conditions of a problem, continued with the deductive diagramming used to solve the problem and the engineering-related computations representing domain-specific behaviors, and culminated in the metacognitive behaviors of planning, clarifying task requirements, review, and cognition of errors. This process initially required feedback from the instructor, again emphasizing faculty-student communication.

Chowdhury (2004) also placed emphasis on student self-evaluation and on team writing assignments for increased metacognitive development as well as improved communication. The author addressed the lack of standardized measurement tools for metacognitive skills by using an anonymous learning self-assessment on the last day of class from which the students' self-confidence and self-assessment of ability with the course content could be gleaned. Although somewhat indirect, through student responses the instructor may glean metacognitive development with students' trends in self-evaluation ability and the responsibility students took for their learning in this course.

Thompson, Alford, Liao, Johnson, and Matthews (2005) described and analyzed a communications approach to college-level engineering education in which engineering students' cognitive development as well as their metacognitive development were promoted. Student reflections were required throughout the three-year program, beginning with unprompted reflections in the first year and continuing in the second year with "What did I learn…" and "What do I plan to do next…" (p. 303) questions. In addition, students were requested to compare themselves to peer group members for identification of their own characteristics on a novice to expert continuum. Although identified as anecdotal evidence by the authors, the reflections appeared to show that learning how to communicate and practicing this skill regularly improved engineering expertise among students. The results also demonstrated the effectiveness of group interactions, even when ability levels differed among group members, and supported the investigation into how widespread are pedagogical practices that improve students' communication skills.

Few authors have examined the connection between the use and development of metacognitive skills and success in college-level sciences for students with LD. Trainin and Swanson (2005) demonstrated that students with LD likely continued to university-level schooling precisely because those students had learned to use metacognitive skills. These authors found that achievement and GPA were related to an increase in metacognitive strategies as well as to help-seeking actions taken by students with LD. However, because the work of Trainin and Swanson (2005) was based on voluntary student participation through the campus learning support center, these authors may have

been sampling the most successful students with LD, due to the fact that not all students with LD contact support services in college (Hall & Webster, 2008). According to Hall and Webster (2008) as well, students with LD who have developed metacognitive skills may be the ones who succeed to the college level. Nonetheless, neither of these reports specified learning in the STEM disciplines, but they offered evidence that pedagogical strategies for encouraging student development of metacognitive skills are important for academic success.

Strawser and Miller (2001) acknowledged the importance of student development of metacognitive skills in their discussion regarding math failure and college students with LD. Specifically, these authors reported that student improvement of self-evaluation and monitoring of problem-solving, organization, and ability to select alternative solution paths when the first one did not work were all enhanced with well-developed metacognitive skills. Research by Flick et al. (2009) recognized the importance of student development of metacognitive thinking skills for recall and transfer of science and mathematics content. Their three-year longitudinal study of undergraduate science and mathematics faculty in five different institutions incorporated qualitative and quantitative analyses of data gathered through classroom observation of teaching. This study showed that even college-level faculty who had already demonstrated interest in improving classroom practices did not teach or encourage metacognitive behaviors. This begs the question of how many engineering faculty are encouraging metacognitive development.

The necessity of the student with LD to become more self-determined in college than was necessary at the secondary school level was addressed by Hall and Webster (2008). In their study the authors found lower self-efficacy among students with LD when compared to non-LD students. The college level students with LD studied by these authors, nevertheless, showed stronger initiative toward assuring their academic success. An active role taken by the student toward his or her education and an understanding of metacognitive processes was determined by Hall and Webster (2008) to be necessary for success in postsecondary education. The importance of self-knowledge about the student's learning disability and in terms of developing metacognitive learning was also supported by Grumbine and Alden's (2006) principles for teaching science to students with LD. In addition, these authors suggested ways the instructor could assist metacognitive learning, such as building metacognitive reflections into assignments and speaking clearly to each student about his or her strengths or struggles.

The relevance of self-esteem and self-efficacy for academic success of students with LD reported in these studies provided evidence that the activities in the classroom and in class-related field settings may be the fundamental sites of success in the sciences for the student with LD (Basista & Mathews, 2002). Contrasting this evidence, however, it has been widely reported that teachers feel inadequately prepared to teach students with LD (e.g., Ahluwalia, 2009; Moin, Magiera, & Zigmond, 2009) and it was also suggested that this lack of preparation negatively affected attitudes toward students with LD as well as lessened student achievement (Vannest et al., 2009). Flick et al. (2009) conveyed that faculty had reported goals of pedagogical change, but did not manifest changes in the

teaching practice. These authors further reported the need for faculty to be aware of and to understand the time, effort, and support necessary to make changes in the classroom.

It may be concluded by these reports that faculty play an important role in student learning. Faculty members, including engineering faculty, must recognize the needs of students with LD, but also be aware of the abilities of this population of students. It is important, therefore, to determine how prepared faculty are to support the learning of students with LD.

Attitudes toward Students with Learning Disabilities

At the college level, students must self-identify their learning disabilities in order to receive the accommodations that enhance their likelihood of academic success (May & Stone, 2010). However, May and Stone also report that students are concerned that they will receive biased treatment from faculty or classmates. The majority of college faculty from STEM disciplines purportedly use teaching methods that they received as college students (Baldwin, 2009). As a result, it has been widely expressed that teachers felt inadequately prepared to teach students with LD (e.g., Ahluwalia, 2009; Moin et al., 2009) and the suggestion was made that this lack of preparation may negatively impact attitudes toward students with LD as well as lessen student achievement (Vannest et al., 2009). This concern demonstrated the lack of faculty understanding and awareness of research regarding learning disabilities and their responsibilities toward students with LD (Casey, 2007).

Classroom Bias

A lack of knowledge by college faculty about the needs of students with LD could lead to biased treatment of these students and their classmates without learning disabilities, as explained by Ahluwalia (2009). This author's initial belief was that a lack of knowledge about a student's disability would prevent him from fairly teaching this student. In fact, Ahluwalia reported that he unfairly disadvantaged the students without learning disabilities, while he provided so much help to the student with LD that he potentially lessened the student's independence and academic development, due to his lack of knowledge about the effects of the disability.

Boysen, Vogel, Cope, and Hubbard (2009) examined bias toward various student groups in college classrooms across all disciplines. Bias was recognized as stereotyping, offensive humor, slurs, insults, among other actions, and was categorized as overt or subtle. Twenty-seven percent of the faculty questioned (n=333) perceived overt bias in the classroom; 30% perceived subtle biases. Of those perceived biases, three percent targeted students with disabilities. Perhaps one of the most important aspects of this research was the disparity between faculty and student perceptions. Among the undergraduates questioned (n=1747), 44% perceived overt and 63% perceived subtle biases in the classroom, seven percent of which targeted students with disabilities. Although all disabilities are included in the reported data, not learning disabilities alone, and the frequency of overt or subtle bias toward students with disabilities is relatively low, the difference between occurrences of bias reported by faculty and by students was high. The authors of this study pointed out that the age difference between most

undergraduates and professors led to different perceptions. The disparity was significant enough, however, to warrant concern over faculty recognition of bias and faculty sensitivity to diverse student groups and also corresponded to Bennett's (2001) recognition that educators needed a strong sense of identity in order to provide an effective multicultural classroom, including students with LD.

Faculty did not perceive themselves to be a source of bias in the study by Boysen et al. (2009); yet, undergraduates occasionally saw faculty as the source of this behavior. The report that student success correlated with self-efficacy (Hsieh, Sullivan, and Guerra, 2007), provided additional concern that student confidence may be undermined in a classroom setting where bias occurs.

Casey (2007) suggested that the greatest barrier in work or school for people with disabilities was the biased attitudes held by others. Such biases could take the form of negative thoughts, but could also be expressed as a lack of academic support services, including reduced faculty interaction with those students with LD. This author indicated, however, that there was a difference between attitudes toward students with LD and "attitudes toward providing accommodations" (p. 92). That is, instructors possibly felt bias toward the requirement of providing accommodations, but did not feel such bias toward individual students. It was a perceived interference to the faculty role and/or the extra workload for faculty—real or perceived—that led to a negative mind-set. Casey showed, however, that faculty willingness to offer accommodations was an important factor leading to success of students with LD.

Less current information was available regarding attitudes of students toward their classmates with LD. Casey (2007), however, reported that in more competitive areas of study, such as allied health fields, students reacted negatively toward students with LD who received accommodations and were reflecting a perception that students with LD were provided an unfair advantage. In addition, May and Stone (2010) compared attitudes from students with and without LD toward individuals with LD. Negative stereotypes continued to exist among both groups of students, although as a result of the small sample of students with LD (n=38), the authors warned against generalization of the results. Both reports offered further evidence that classroom attitudes are relevant to student learning.

Accommodations

Brinckerhoff et al. (2002) defined accommodations, defined as provisions for equal access for all students to college programs and services in a meaningful way. This means that circumstances are created for students with LD providing course content equitably, when compared to students without LD. Sweener, Kundert, May, and Quinn (2002) surveyed faculty members at a community college regarding their comfort levels at providing accommodations for students with LD. Most faculty were comfortable providing some types of accommodations for students; however, many more were uncomfortable (46%) than comfortable (27%) when accommodations required more time or effort on the part of the faculty member, such as offering more frequent exams. Although in this study 12% of the faculty participants came from the engineering

division, the researchers observed no significant difference in results of the survey for accommodation comfort by academic division.

Upon examining attitudes of faculty toward accommodating student with LD at a New Jersey university, Smith (2007) found some differences among academic disciplines. For example, faculty from liberal arts and sciences and from engineering were more likely to believe that students with LD took advantage of accommodations than were faculty from communications, fine arts, or education. Aligned with this result, perhaps, Smith also found that faculty from liberal arts and sciences believed that student with LD were more capable of success in college than did communications faculty. Scott and Gregg (2000) reported differences in attitudes among college faculty from various disciplines as well. Faculty from social sciences and education had more positive attitudes toward providing accommodations for student with LD. In addition, faculty with more teaching experience reportedly possessed more positive attitudes than faculty with less teaching experience (Scott & Gregg, 2000; Smith, 2007). Faculty attitudes toward students with LD improved with increased training on the needs and abilities of students with LD (Sowers & Smith, 2004), supporting the effort of determining faculty knowledge of the needs of students with LD.

Sowers and Smith (2004) found no research for training or describing students with LD in nursing programs. These authors surveyed faculty members from eight nursing programs before and after a training program called “A Day in the Life of a Nursing Student” (p. 249). Initially, nursing faculty possessed a more positive attitude toward nursing students with some physical disabilities, such as deafness, than they did

toward students with LD. After the program, which included recorded interviews with professional nurses who displayed various disabilities, including learning disabilities, the faculty members' responses were statistically significantly more positive. Once again, training improved faculty attitudes toward students with any disabilities and highlighted the importance of faculty knowledge regarding the population of students with LD.

Pedagogical Strategies for the STEM Disciplines

Wenglinsky (2002) used a national database to examine mathematics teacher quality in relation to student achievement. This study did not use college-level classroom data, but it provided a general effect between classroom instruction and student achievement that may apply to the postsecondary setting. Of the teacher characteristics in Wenglinsky's study, the practices a teacher used in the classroom showed the greatest effect on student achievement. Active teachers who used more hands-on learning methods and who recognized differences in individual student backgrounds that led to differences in student preparation for the course, demonstrated multiple solution paths in classroom instruction. With this type of instruction, student achievement was higher, compared to the students who received passive instruction, and provides inspiration for the examination of pedagogical strategies used by STEM faculty members.

Traditional Instructional Strategies

In discussing their analysis of science instruction and epistemic technological tools used to assist student development of scientific thinking over simple accumulation of scientific facts, Sandoval and Reiser (2004) conveyed that postsecondary science faculty typically act as the science experts who present course content as a collection of

discovered facts without including the history and development that led to those facts. In their research for improvement of college engineering instruction Akerson et al. (2002) also recognized that most college-level science instruction commonly revolved around a lecture presentation of course content with no active student involvement.

The lecture is acknowledged as the most common pedagogical method used in science and engineering courses, but this teaching strategy does not assure student understanding of science concepts nor does it typically encourage the creative thinking that science and engineering content might engender among students (Akerson et al., 2002; Hrepic, Zollman, & Rebello, 2007). Although cultivating passivity among students, the lecture teaching approach reportedly continued in most engineering and pre-engineering courses (Akerson et al., 2002; Ferrini-Mundy & Güçler, 2009). While science and engineering instructors have been seen to make efforts at integrating content through their lecture presentations in an effort to assist student understanding (Froyd & Oiland, 2005), it is the students who must organize and connect new content to their prior knowledge in order to learn, according to constructivist-based learning models (Hrepic et al., 2007). Hrepic and his colleagues investigated physics students' understanding during a lecture. The results demonstrated that instructors have a tendency to believe students can make generalizations and draw inferences from lectures more than students can. The authors recommended that instructors direct and watch closely students' cognitive processes with interactive technologies, such as clickers.

A study by Sandoval and Reiser (2004) examined student use of an interactive computer program for assessment of conceptual understanding. The process of

memorization or other rote learning strategies, chosen by students for study of the traditional factual presentation, did not cultivated deep learning, according to the science instruction analysis by Sandoval and Reiser. Students' cognitive development required the monitoring and feedback available through the technological tool for greater learning. Wieman (2007), in fact, suggested that scientific evidence for how students learn should be used in developing science teaching practices, rather than tradition or anecdotal evidence that has been commonly used by instructors for making decisions about educational practices.

DiCarlo (2009) identified the ineffectiveness of the traditional lecture format for developing meaningful learning in the sciences. Although this author focused on physiological sciences, his reported research results that demonstrated greatly diminished student attention after 10 – 15 minutes, may apply to students in any science. Tied to the reduction of student learning through traditional science lecture presentation, Sundberg (2003) proposed that the misconceptions students commonly bring to a science course are not successfully overcome by a passive lecture format. Wieman (2007) also supported a reduction of the lecture approach when he described a widely used assessment for determining student understanding of physical concepts, called the Force Concepts Inventory (FCI). Students whose instructors used interactive pedagogy showed higher FCI results than students whose instructors used a lecture-oriented pedagogical approach. Wieman's assessment that the traditional lecture was not a successful method for encouraging student mastery of concepts provided further support for innovative instructional methods.

Schuster and Carlsen (2009) studied teaching methods used by university and research scientists, whose research interests aligned with the interests of the National Aeronautics and Space Administration, during the scientists' presentation of professional development workshops for secondary school science educators. The authors used observations and a continuum of pedagogical orientations to assess the pedagogy used by the scientists in the workshops. Three pedagogical categories reflected the theoretical approaches used for teaching by the scientists and were labeled conceptually-based/substantive, experience-based/syntactic, and neutral. The collected views of the teacher workshop participants provided qualitative data included in the analyses for this study.

Results from the Schuster and Carlsen (2009) study compared the workshop goal of experience and inquiry-based activities to the actual instructional methods used, which were, in fact, conceptually-based/substantive, lecture-oriented presentations. The research demonstrated that the scientists did not believe the teacher participants possessed the prior knowledge and experiences necessary to allow inquiry-based activities. While the majority of the teachers participating in the workshop agreed that they were not prepared for experiential exercises, it was noted by the participants that the scientists had not modeled the inquiry methods on which science is based. In concluding that scientists did not engage even the community of learners who brought enthusiasm for the content to the learning environment, Schuster and Carlsen also demonstrated evidence of the deep entrenchment of the traditional teaching methods among science educators.

College-level instructors are not required to complete courses in education, including pedagogy, so are said to teach as they were taught (Baldwin, 2009; Halpern & Hakel, 2002; Wieman, 2007). As a result, there is evidence that utilization of alternative pedagogical strategies presents challenges for many science and engineering instructors (Akerson et al., 2002). The Nobel Prize winning physicist, Carl Wieman (2007), supported the cause of educational reform when he encouraged faculty to utilize educational research on learning, rather than rely on tradition or anecdotes to make decisions about pedagogy. His own classroom research and observations led to his assessment that the traditional lecture was not a successful method for encouraging student mastery of concepts and supported faculty development of alternative teaching strategies that would make science content accessible for all students.

Access to Academic Content for Students with LD

Traditionally, college engineering courses have required a solid background in mathematics and the sciences (Dym et al., 2005). After the necessary background was established, students enrolled in engineering courses. First-year engineering courses offered students little connection to real-life engineering tasks and usually included no direct contact with engineering faculty (Dym et al., 2005). This pattern contradicts research by Lundberg and Schreiner (2004) demonstrating that the quality of a student's relationship with the faculty significantly predicted student learning.

Teaching science content in order to meet equally the needs of students with and students without LD reportedly required an instructor to make a few pedagogical changes (Flick et al., 2009; Grumbine et al., 2005). The thoughtful consideration of how to

present content and how best to involve students resulted in improved learning for all students (Grumbine & Alden, 2006). Many authors offered ideas for curriculum development that emphasized better learning for all students, but which also supported science learning for the student with LD, such as small group discussions, applied experiences, and utilization of technology and out-of-class and field activities (Ferrini-Mundy & Güçler, 2009; Flick et al., 2009; Grumbine & Alden, 2006; Kurtis, Matthews, & Smallwood, 2009; Moin et al., 2009; Scruggs & Mastropieri, 2007; Vannest et al., 2009).

Wieman (2007) presented a plan that considered cognitive learning theory when designing science lessons. He suggested that instructors consider the limits of working memory and plan instruction with reduced cognitive load in mind. In addition, he emphasized the importance of developing carefully planned homework and timely formative feedback to take advantage of students' prior knowledge as well as to enhance long-term memory development. His suggestions were not offered for students with LD specifically, but they harmonized with previously identified suggestions from authors, such as Scruggs and Mastropieri (2007), who specifically addressed the needs of students with LD when they recommended keyword mnemonic method that utilized a mental picture and a keyword linked to the scientific term. The authors repeatedly found mnemonic strategies to be very effective for learning science content when used by students with LD. From their extensive teaching experience with students with LD, these two authors also recognized that the use of reading comprehension strategies that distinguished text structures for identifying the main idea, any examples, and sequential

details in the content of the text served students with LD well in their study of the sciences. Even though such mechanisms could aid student vocabulary and content acquisition, many authors recommended that instructors make efforts to reduce course content for student success in the sciences (Grumbine & Alden, 2006; Huang-Pollock & Karalunas, 2010; Smith, Douglas, & Cox, 2009; Wieman, 2007). An example of this approach was seen in the calculus reform described by Leviatan (2008) which led to reduction of content. The content reduction resulted in faculty concerns regarding course credibility, however. Smith, Douglas, and Cox (2009) addressed science, technology, engineering, and mathematics educators when they used the phrase "courage to relax our coverage compulsion" (p. 30) toward support of alternative instructional strategies that support learning and engage most of the diverse student population.

Scruggs and Mastropieri (2007) compared constructivist and content-driven models for enhanced science learning, particularly for students with LD. The content-driven model, which emphasized a direct acquisition of facts, relied heavily on language skills for increasing breadth of details and vocabulary. In contrast, the constructivist model led to comprehension of concepts and was focused on depth of learning rather than breadth. These authors explained that with the constructivist model there was less emphasis on rote learning and more emphasis on meaningful experiences that developed student learning at a deeper level than memorization of relatively more superficial facts demonstrated. Interestingly, these authors found that both the content-driven and constructivist models demonstrated useful elements that promoted science learning for students with LD. They encouraged faculty to plan highly structured statements that

allow many students with LD to draw conclusions and construct scientific knowledge through development of deductive reasoning. Although the authors referenced the debate between constructivist and content-driven models in science education programs, they also pointed out that because completion of education courses was not required for college instructors, many college faculty were frequently not aware of the instructional methods that best served students with LD in the sciences.

Although efforts to make college physics courses accessible to all students reportedly began in the 1980's, Ferrini-Mundy and Güçler (2009) described recent professional meetings at which science educators including those from physics, chemistry, mathematics, and engineering, continued to work on developing physics courses that were accessible to all students. The discussions, recounted by the authors, supported undergraduate physics reform that would be effective for students with a wide range of interests in the sciences and mathematics in order to encourage, not discourage, pursuit of majors in mathematics, sciences, and engineering. Fundamentally, the authors described the institutions that house the widely recognized successful physics departments as those that display commitment and apply resources toward student success, undergraduate research opportunities, and evaluation of student success as the departments connected to a climate of improvement. The conclusions from these authors demonstrated that providing access to science content for all students, including students with LD, is likely an institution-wide process.

Student Engagement

A fundamental improvement to pedagogy involved increasing student interest and learning by engaging students to become more involved in their learning (Wolf-Wende, Ward, & Kinzie, 2009). Wolf-Wendel and her colleagues used results from the National Survey of Student Engagement project to define student engagement. The authors analyzed current educational literature to establish the importance of high levels of student engagement to college success for all disciplines of study. The work of these authors established the association of high measures of student engagement with both outstanding student-faculty interaction and collaborative student learning.

Research by Hrepic et al. (2007) that examined the level of student learning through high-quality lecture presentations supported the need to use pedagogical methods that increase student engagement. Although student participants had previous class experience with a physics topic and had received the six pre- and posttest questions prior to the experimental lecture, only one or two of the 18 student participants answered any but the simplest questions correctly. Student success at inferring correct answers from the lecture was also very low, totaling four correct inferences during the study, all from students with identified prior knowledge of the topic. These researchers advocated active learning actions, including the use of clickers during class, as supported by Wieman (2007) to enhance student engagement. The work of these authors exemplified the importance of pedagogical methods in improving student engagement.

Task-centered and active learning approaches. In a synthesis of STEM teaching and learning strategies Smith, Douglas, and Cox (2009) reported that students

who identified their college majors from the sciences, mathematics, and engineering as well as those who did not identify majors from these disciplines, reportedly widely perceived "poor quality learning environment" (p. 20) in college mathematics and science courses. These authors encouraged instructors to utilize the more informal active learning and problem-solving learning methods, including use of cooperative in-class student groups. Not only were students reported to improve critical thinking skills, but interaction among students through cooperative learning increased the sense of community among students from the STEM disciplines, perhaps improving student retention in related majors.

Aligned with the concept of increased student involvement, Michael (2006) reduced the ideas from several sources into five key concepts inherent in and supportive of active learning in the science classroom. Some of his key concepts applied to the learner; some applied to the instructor. The concepts that revolved around learners included the necessity to actively construct meanings, articulate explanations for themselves, and work collaboratively with their peers. Concepts that centered on instructors emphasized their recognition that learning facts is a different process from learning procedures and that the instructors understand the domain-specific nature of some learning processes as well as recognize that other learning can be transferred across domains.

Active learning, defined as learning strategies that engage student participation in the attainment of knowledge (Michael, 2006), focused on student actions in the classroom rather than on the instructor. The teacher acted as a facilitator for student activities that

led to learning (Colón-Berlingeri, 2010; Michael, 2006). Evidence exists demonstrating that active learning methods led to improved science literacy (Sundberg, 2003), a greater understanding of physical chemistry, and improved understanding of mechanics in introductory physics (Michael, 2006).

An instructional approach in a college-level biology class, built around real-world tasks during which students applied the concepts and definitions they studied was employed by Francom, Bybee, Wolfersberger, Mendenhall, and Merrill (2009). These authors recommended this teaching approach because the majority of students reported the process incorporating the real world tasks helped them learn. In addition, assessment evidence indicated that a task-centered approach increased critical thinking. This effort was designed to add to the students' mental models and to development of their deep learning of biological concepts. However, the authors qualified the results because there was no student group that received a traditional lecture-style instructional approach for comparison.

Continuing pedagogical strategies to increase student involvement, Wagner (2009) used what was called an interactive anonymous quiz (IAQ). The IAQ offered the comfort of anonymity to students during in-class responses, while requiring little or no instructor preparation. Wagner described and recommended this process, with or without the personal response units, commonly called "clickers," for assessing student learning in a college chemistry class as well as for the introduction of new topics and for making transitions between topics. Wagner found that the IAQ process led to increased class discussion and student engagement.

The core concepts of active learning articulated by Michael (2006) were recognizable in the instructional approach of Moin et al. (2009). The core principle offered by these authors centered on tasks in which language skills were de-emphasized in favor of concrete tasks, such as the design of scientific investigations. Lesson plans that used or manipulated equipment or that allowed students to record data, analyze results, and discuss findings were encouraged as were naturalistic observations. Group activities were also favored in order to promote the skills of each student and expose the specific talents of students with LD as well as their non-LD classmates. Peer work and hands-on laboratory activity were also emphasized by Wieman (2007), because students "learn by creating their own understanding" (p. 12). In addition, Wieman advocated the use of technological tools, such as simulations that may enhance student understanding of concepts in the sciences. In addition, this author's recommendation of using "clickers" offered a mechanism for incorporating all students, with either more or less assertive personalities, into discussions and question-answer sessions. Such technological methods may be utilized by the student with LD as well as the balance of the students in a class and may be aligned with the methods recommended by the Iowa Center for Assistive Technology Education and Research (Rule, Stefanich, Haselhuhn, & Peiffer, 2009).

Task-oriented and hands-on approaches to teaching in the sciences improved accessibility for students with disabilities, including students with LD, in addition to improving self-efficacy in the sciences for this student population (Melber & Brown, 2008). Such hands-on work in the sciences, including laboratory exercises and experiments caused no safety problems for students with LD (Moin et al., 2009; Scruggs

& Mastropieri, 2007). On the contrary, Scruggs and Mastropieri (2007) reported that both LD and non-LD students who were taught with a hands-on focus outperformed students using text-based instruction. Incorporation of demonstrations into instruction, especially those that include student effort in the process, served to enhance learning (Grumbine & Alden, 2006).

All of these authors not only demonstrated methods that may engage students with LD into the sciences, but provided evidence of the academic success this population of students is capable of exhibiting in the sciences. Scruggs and Mastropieri (2007) further pointed out that enthusiasm displayed by an instructor added to the likelihood of successful of hands-on work by students. It was when teachers created an environment that allowed student involvement in active learning that student interest and connectedness to the topic occurred (Colón-Berlingeri, 2010; Michael, 2006).

Peer group work. Considerable research has demonstrated that student peer work benefits student success in the sciences. For example, peer discussions among students have been shown to promote active learning (Smith, Wood et al., 2009). The actions of talking to one another, including the articulation of one's understanding of concepts, justifications, explanations as well as questions to peers, were considered factors that resulted in successful cooperative learning (Michael, 2006; Smith, Wood et al., 2009). Group discussion and debate that reflects increased engagement among peers resulted in greater conceptual understanding (Smith, Wood et al., 2009). Chung and Behan (2010) concurred when they reported that utilization of small, inquiry-based group projects aided science learning.

Chung and Behan (2010) also shared that, in addition to improving communication and application of science knowledge, the use of activities that incorporated group learning improved student motivation. According to Michael (2006), cooperative learning with peers as well as other active learning techniques, such as open-ended problems and student simulations also led to students who were more motivated to learn with deeper understanding and more positive attitudes. In addition, peer support was suggested as a possible beneficial consequence of using universal design for learning (UDL) in relation to one of the fundamental design mandates to provide multiple methods for engaging students in learning (Kurtis et al., 2009).

Cooperative learning. The effectiveness of another aspect of student engagement recognized by Wolf-Wendel et al. (2009), that of cooperative learning, has also been demonstrated by various authors. Smith, Douglas et al. (2009) encouraged instructors to utilize the more informal active learning and problem-solving learning methods, including use of cooperative in-class student groups. Not only were students reported to improve critical thinking skills, but interaction among students through cooperative learning increased the sense of community for students from the disciplines of sciences, mathematics, and engineering.

A specific type of cooperative learning particularly relevant to engineering, called project-based learning (PBL), was the focus of the study on learning and teaching in engineering by Dym et al. (2005). The authors described PBL as a multidisciplinary practice that encourages collaboration and improved engineering design thinking. In addition, when utilized for first-year engineering students, student interest and retention

were enhanced. When the authors compared retention rates of engineering programs using first-year PBL practices to national retention rates in engineering programs that did not use PBL during the first year, they found that retention was 86% compared to 70% nationally for all students and was 86% compared to the national level of 67% for minority students. Female students showed a two percent improvement in retention.

Amenkhienan and Kogan (2004) recognized that peer interactions, even in less formal settings, were important for improved learning outcomes among engineering students. The peer interactions examined by these authors included networking with fellow engineering students and study groups. Female and ethnic minority students reported greater comfort when other engineering students were members of the group to which they could best relate. In addition, students perceived benefit through teaching each other and learning from peers in study groups.

Integrated Curricula

Among the first developments of a paradigm shift in engineering education to improve student interest and retention was what could be called an integration of disciplines using cross-disciplinary programs that seek to improve communication and leadership skills along with engineering skills (Splitt, 2003). This integration of disciplines reflected the growing concern, not only that many engineering students were not graduating, but that those who did graduate were not well-prepared to interact professionally with industry or the public to undertake engineering tasks (Crawley, Brodeur, & Soderholm, 2008; Ferrini-Mundy & Güçler, 2009). Institutions that have made an effort at engineering education reform have combined engineering with

biological sciences, with political science, or with the humanities, for example (Splitt, 2003). All such integrations resulted in improved student ability to make connections necessary for problem solving (Froyd & Oiland, 2005). Work by Crawley et al. (2008) further emphasized student development of interpersonal skills through integrated learning experiences.

In the engineering education community an important outcome of integrated curricula, described by Froyd and Oiland (2005), was the development of learning communities among students. Social connections as well as academic connections were found to enhance teamwork skills among students. In addition, the student affiliations that developed had the effect of increasing persistence among female and ethnic minority students, although students with LD were not addressed in this work.

Universal Design for Learning. With origins in response to the Architectural Barriers Act of 1968 to assure physical access to buildings to all people, universal design has been promoted for education settings to assure that all students have access, not only to the physical school structures, but to the content of academic programs (Hitchcock & Stahl, 2003; Pilner & Johnson, 2007). The seven principles developed by the Center for Universal Design at North Carolina State University (www.ncsu.edu) were created for application to all products and environments. In summary, these principles include equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and size and space for approach and use (Hitchcock & Stahl, 2003).

Several authors have acknowledged, however, that the universal design principles needed reconstruction specifically for use in educational settings (Hitchcock & Stahl, 2003; Pilner & Johnson, 2007; Scott et al., 2003). Scott et al. (2003) expanded and revised the original principles to nine principles for instructional use: equitable use, flexibility in use, simple and intuitive, perceptible information, tolerance for error, low physical effort, size and space for approach and use, a community of learners, and instructional climate. These authors incorporated the interactions among faculty and students, including a welcoming and inclusive learning environment, within their edition of the universal design principles.

The term universal design for learning (UDL), called universal instructional design by some authors (Pilner & Johnson, 2004), was legally defined by the Higher Education Opportunity Act of 2008 (Edyburn, 2010). The text of this act expresses recognition of UDL as a scientifically valid guiding educational principle that provides for flexibility in presentation of content, in methods for student demonstration of knowledge, and of methods of student engagement (U.S. Public Law 110-315). Various authors have continued to develop instructional strategies based on the original universal design principles in combination with the multiple ways of representing content, multiple methods of expression by students, and multiple ways for student engagement (e.g., Grumbine et al., 2005; Kurtis et al., 2009).

Aligned with cognitive learning theory in addition to UDL, the six principles provided by Grumbine and Alden (2006) offered guidelines for lesson development that meet the needs of students with LD in the sciences as well as the science learning needs

of all students. These principles arose from development of the *Biology Success!* program funded by the National Science Foundation (Grumbine et al., 2005). Reflecting UDL, the program's first principle recommended using various methods to teach to diverse learning styles, such as utilization of demonstrations, diagrammatic exercises, text-based, and role-playing activities. The multiple means of representing content offered multiple means of expressing content mastery by students. Four of the six principles set forth by these authors recommended explicit instruction and objectives combined with clear organization and consistent feedback. Routines, organization, and feedback reduced extraneous cognitive load and guide students in the cognitive processes of learning. The final principle offered encourages development of students' development of metacognition by building reflections on learning into assignments.

Kortering, McClannon, and Braziel (2008) applied UDL interventions to college algebra and biology courses to compare perceptions of the intervention in student groups with disabilities (n=37), nearly half of which were students with LD, and without disabilities (n=253). Among the outcomes of this study, the researchers found that students took pleasure in learning under the UDL approach. In addition, both student groups assessed favorably the usefulness of the course content with the UDL approach, compared to their other academic classes. Students were reported to have enjoyed the various methods used, such as peer work, hands-on activities and the use of technological tools. The authors also suggested that the use of UDL had the potential of changing pedagogical beliefs held by instructors, an act that was acknowledged to be usually very difficult.

Some authors have supported the use of UDL or Universal Design for Assessment (UDA), both of which were designed to support learning for all students, including students with LD (Ahlgrim-Delzell et al., 2009; Casey, 2007; Ketterlin-Geller, 2005; Kurtis et al., 2009). Kurtis et al. (2009) presented in detail a physical science lesson that combined the three essential components of this type of lesson design: multiple ways of representing content, student expression, and student engagement. This design demonstrated incorporation of cognitive learning theory, as did the principles set forth by Grumbine and Alden (2006). Kurtis et al. (2009) offered mechanisms for instructors to set instructional goals and to develop rubrics for assessment of the diverse activities incorporated in a science UDL lesson for secondary educational settings that may have application for post-secondary educational settings. These authors also suggested creation of a K-W-L chart for each lesson. This chart engaged students in the learning process and activated their prior knowledge by asking them to write what they knew (K) prior to the lesson, what they wanted to know (W), and what they learned (L) after the lesson.

In their study of learning strategies for STEM disciplines, Smith, Douglas et al. (2009) recommended undergraduate learning environments that provided a sense of security for students, allowing them to ask questions and work collaboratively in comfort. These authors also supported the use of multiple methods of assessing student learning, as typifies universal design.

Ketterlin-Geller (2005) advocated planning for assessment of all students using UDA. She reported that most assessments made to incorporate accommodations for

students with LD retrofitted previously created assessment tools. The author briefly outlined steps for development of assessments, beginning with clear definition of outcome to be assessed, including minimization of extraneous variables. This plan agreed with Wieman (2007) who asserted that a science instructor must develop learning outcomes that were specifically gauged to student demonstrations of desired learning and capability. Consideration of a flexible format for the assessment was recommended as a response to needs of diverse students. Care was also suggested in determining the test environment to suit various student needs.

Conclusions drawn by Sparks and Lovett (2009) after their examination of empirical studies regarding students with LD at the college level included their support of UDL. These authors found inconsistencies in criteria used to identify students with LD. Student achievement scores and academic abilities greatly overlapped between students with and without LD. The use of UDL in the college classroom was suggested to negate the impact of overlapping abilities among all students.

Faculty Development

The studies examined thus far have demonstrated some of the various pedagogical methods used by science, mathematics, and engineering faculty as well as the pedagogical methods that lead to improved accessibility to the sciences and mathematics for all students, including students with LD. However, classroom use of UDL methods, including an emphasis on student metacognitive development and active learning approaches, have been reported only within special programs, such as *Biology Success!* (Grumbine et al., 2005). It is unclear whether science, mathematics, and engineering

faculty are aware of the research on various instructional strategies (Hitchcock & Stahl, 2003) or on the benefits to student learning of uncovering their misconceptions (Modell et al., 2005). Lombardi, Gerdes, and Murray (2011), however, suggested that it is not likely that many college faculty have the knowledge that students with LD report more success in supportive, inclusive classrooms that utilize more universal design principles.

One pathway to improvements in pedagogy may be found through faculty development programs and activities. Ouellette (2004) recognized that faculty members are interested in quality pedagogical methods, but often most resources were available for faculty research interests and other scholarly endeavors, not for faculty development of pedagogy. University faculty members from the study by Smith (2007) expressed the need for more resources and training in order to learn to meet the needs of students with LD.

When Sowers and Smith (2004) assessed knowledge of and attitudes toward students with LD by nursing faculty before and after training that centered on nursing students with disabilities, they found low levels of knowledge and negative attitudes toward this population of students. While not all faculty participants in the eight nursing programs studied were willing to answer questions regarding their perceptions and concerns, survey results showed a significant improvement in attitudes toward students with disabilities. The largest difference was observed in improved attitudes toward students with LD. Although the authors provided the qualification that the training for faculty was voluntary, their evidence supported the value of faculty training regarding students with disabilities, including learning disabilities.

Engineering faculty from EEC coalition member institutions were reportedly very creative in developing cross-disciplinary curricula and in utilizing instructional methods that incorporated new technologies, such as digital media tools (Fromm, 2004). However, Fromm's review of the new engineering paradigm addressed retention of underrepresented minority and female students, but there was no mention of students with LD. In fact, in a study of 700 publications contributed by four of the eight EEC coalitions through 2005 Borrego (2007) found no journal articles devoted to women or minorities, even though improving retention for these student groups was one goals of the engineering reform (Wulf & Fisher, 2002). Borrego (2007) also pointed out that many of the 700 "research" articles did not utilize the criteria for research, including educational research. Seventy-four percent of the publications fell into the "author experience" category. Borrego reported that critics of engineering education reform efforts believe that it would be education researchers who could assist reform in engineering fields more effectively. The study by Borrego indicated indirectly that there is continued need for faculty development among engineering educators, even those from coalition institutions, to improve knowledge and awareness of diverse student needs, including students with LD.

Smith, Douglas et al. (2009) reported that it had not been ascertained whether college faculty had evaluated the research on active learning teaching approaches. Although these methods commonly necessitate a reduction of course content, greater student accessibility to content and learning was expected. In addition, Hitchcock and Stahl (2003) indicated that universal design standards had not been consistently

implemented by educators. They recommended that research be conducted to determine what is necessary to assure full participation by diverse learners. These authors reflected the pattern of work by individual faculty members on improving teaching methods without widespread communication of results.

In his review of the first decade of UDL, Edyburn (2010) proposed new directions he believed were needed in order to reach the promise of UDL. Included in his propositions was the recognition that UDL is a learned cognitive skill. With no requirement of schooling in the field of education for college-level instructors, it may be common that college science, mathematics, and engineering faculty have not learned this skill. Work to improve faculty knowledge of this skill and other pedagogical skills was supported by the assessment that UDL had the potential for changing pedagogical beliefs held by instructors (Kortering et al., 2008).

The research of Gess-Newsome, Southerland, Johnston, and Woodbury (2003) emphasized the need for incorporating instructors' pedagogical theories into educational reform efforts. In their analysis of beliefs, pedagogical practices, and observations of individual science faculty, these authors recognized the importance of utilizing the conceptual-change theory as a basis for any pedagogical changes to college-level science instruction. It was the determination by these researchers that the personal factors and beliefs of college science teachers provided the most relevant data for understanding the pedagogical practices used. The authors stated that the science faculty may require "unlearning" (p. 738) or conceptual change to enact any reforms. In conjunction with this idea, Duschl's (2008) statement that "science and scientists are responsive" (p. 274),

expressed the optimistic belief that STEM faculty will respond to new information provided regarding the abilities and needs of students with LD.

Theoretical Framework

Several learning theories provide a foundation for this study. With an expectation that many STEM faculty bring inaccurate beliefs about the abilities and needs of students with LD to the classroom, through lack of knowledge, the conceptual change theory offers a framework from which faculty may be able to shift their beliefs about students with LD. This study, in addition, seeks to verify the learning theories faculty use through their pedagogical strategies that support learning of students with LD. Experiential learning theory, social cognitive theory, and the concept of universal design are addressed.

Conceptual Change Theory

The conceptual change theory fundamentally motivates this study. This learning theory centers on the learner's development of internally created mental conceptual models and the conditions required for conceptual changes (Posner et al., 1982). The conceptual mental models and the mechanisms for conceptual changes were founded by these authors in science and mathematics learning.

Whether a student brings no previously constructed mental model for a topic or brings misconceptions to the learning environment, it is the internal cognitive process of conceptual change that usually slowly leads to creating a new cognitive mental model of a topic (Modell et al., 2005; Vosniadou, 2007). It is the responsibility of the educator to provide the learner with the opportunities and tools necessary for recognition, repair, and

reorganization of the accurate concept (Cunningham & Wescott, 2009).

The study by Schuster and Carlsen (2009) also provided a framework for incorporating the conceptual-change theory into pedagogical changes that could be made by science faculty. It was twenty-five years ago that Carey (1986) recognized that science educators and cognitive scientists needed to work together to understand and develop solutions to the problem of misconceptions for development of scientific knowledge. Application of the principles from research on misconceptions (e.g., Cunningham & Wescott, 2009; Leviatan, 2008; Modell et al., 2005) to science, mathematics, and engineering faculty could promote the relationship between science education and cognitive science toward improvement of learning in the STEM disciplines for *all* students.

Research regarding the conceptual-change theory typically addressed student learners and the related actions by faculty to enhance development of new conceptual models. Because the student is not a scientist, conceptual change is reported to be a gradual process that may require some time and that may be influenced positively or negatively by the context and by social processes (Li, Law, & Lui, 2006; Vosniadou, 2007). In contrast, conceptual change for the scientist can be an immediate shift when the scientist "is faced with a challenge to his basic assumptions" (Posner et al., 1982, p. 212). The premise of this study is that the conceptual-change theory, including the immediate conceptual shift, may also be applied to faculty members. Conceptual change theory may be appropriate if a faculty member's current conceptions of student learning have led to unwillingness or inability to recognize the need for pedagogical changes that

assure students with LD and all students have access to course content. This theory, therefore, offers the rationale for the recalcitrance of some faculty from engineering regarding pedagogical creativity for increasing student access. In addition, the conceptual change theory offers the framework for approaches to faculty professional development of instructional knowledge necessary to teach all students, including those with LD.

Experiential Learning Theory

Much of the pedagogical engineering literature demonstrates that teaching strategies are based on experiential learning theory. This theory is represented as a cycle that begins with an experience, followed by reflection and development of abstract concepts. The cycle is completed with plans for using or experimenting with the concept (Kolb, Boyatzis, Mainemelis, 2001). Kolb expressed that experience was a transformative process for a learner in which knowledge is created. An example of its use in engineering is supplied by what Crawley et al. (2008) called the Conceive, Design, Implement, and Operate (CDIO) cycle for aerospace engineering design. An experiential learning method, the authors also define it as an active learning practice.

Experiential learning in engineering may also be expressed by the pedagogical approach called project-based learning (PBL). Engineering students experiencing PBL begin by defining the problem, thinking through a design solution, including anticipating all possible consequences to the design as well as appropriately estimating the parameters of the design (Dym et al., 2005). Through the PBL process, including the experiments

performed to test the design, collaboration is encouraged, adding to the real-world experience of the learning process.

Social Cognitive Theory

In his chapter on science education Duschl (2008) expressed that current science classroom teaching methods incorporate social processes into scientific inquiry. According to this author, the instructor must be a manager of the ideas acquired by the learner as well as of the student's interactions with other students. This links to social cognitive theory in which the work of the mind is incorporated with human social factors (Bandura, 2001).

Because topics of STEM disciplines are often complex, cooperative or peer group activities, based in social cognitive theory, may be appropriate (Hartman & Branoff, 2005). Specifically, instructors from engineering disciplines may be seen as practitioners, not science researchers (Borrego, 2007), who present real-world problems within the engineering curriculum which are often very complex. Therefore, peer interaction that results in an academic group product may be appropriate for learning and is founded in the realism of how an engineer interacts with others in the professional world (Hartman & Branoff, 2005). Self-efficacy for the resulting product, a byproduct of social cognitive theory (Bandura, 2001), provides additional merit for the social context of learning in engineering.

Concept of Universal Design for Learning

The literature does not provide evidence that the concept of UDL has been utilized in engineering curricula. Because the use of the universal design concept may

best support students with LD, it is addressed here. The premise of UDL is that students are provided with multiple methods of experiencing course content, multiple methods of expressing their learning, and multiple types of engagement opportunities (Kortering et al., 2008). UDL is founded on a flexibility of presentation of content and assessment of learning that allows all students from any background or with any type of disability to learn.

Seven principles for UDL were originally developed in the field of architecture to assure that all people had physical access to all public sites. Two principles were added for application to educational settings (McGuire, Scott, & Shaw, 2006). McGuire et al. briefly present these principles as equitable use for all people; flexibility of instruction design; simplicity to eliminate unneeded complexity; perceptible information; tolerance for error; low non-essential physical effort; consideration for size, space, and approach of use; a community of learners; and an inclusive instructional climate.

CHAPTER 3: METHODOLOGY

There were three assumptions that constituted the foundation of this quantitative study. The reports that academic success for students with learning disabilities (LD) is declining in the sciences, mathematics, and engineering (Vannest et al., 2009) were accepted and represented the motivation for a pedagogical study of college-level sciences, mathematics, and engineering. Further, it was assumed that faculty from the sciences, mathematics, and engineering want all their students to succeed academically and that faculty from these disciplines hold empirical research in high regard, as indicated in Colbeck's (1998) research on faculty integration of research and teaching. Colbeck provided evidence that faculty from the natural sciences, in particular, valued the empirical research process. The work supported the expectation that faculty from the STEM disciplines would show willingness and be interested in changing pedagogical approaches that would lead to improved academic success for students, including those with LD. Yet, with a few individual or programmatic exceptions (e.g., Akerson et al., 2002; Grumbine et al., 2005), most faculty from these disciplines use the pedagogical strategies they experienced as students, usually the traditional lecture format (Baldwin, 2009).

With this foundation, this study sought to determine what current pedagogical approaches were practiced in college-level engineering courses and whether engineering faculty had been trained in pedagogy, so were able to apply learning theory and pedagogical research to their instructional strategies. In addition, this study attempted to determine whether engineering faculty incorporate into their teaching opportunities to

assist students in development of metacognitive strategies, which have been shown to be especially useful in improving learning for students with LD (Hall & Webster, 2008). Finally, effort was made to determine engineering faculty attitudes toward students with LD and their willingness to try new pedagogical approaches for improving student learning, especially for students with LD.

Some studies have examined faculty perceptions and attitudes toward students with LD (e.g., Smith, 2007; Sweener et al., 2002), but none has focused specifically on perceptions and attitudes of college-level engineering faculty. Further, no study has previously examined the level of teaching education possessed by faculty from engineering with connection to instructional approaches toward students with learning disabilities. Results from this study may serve to inform professional development programs for faculty during departmental faculty orientation as well as throughout a faculty member's service at the institution. The resulting data collected could clarify the cause of the apparent gap between the college-level instruction in engineering and the academic success for students with LD.

Research questions

1. What educational backgrounds do engineering faculty members have that provide them knowledge of learning theory and pedagogical research? Have engineering faculty taken education courses?

2. What pedagogical and assessment approaches do engineering faculty members use in college-level engineering courses?

3. What teaching strategies that assist student development of metacognitive skills

do college-level engineering faculty members incorporate into their teaching?

4. (a) What are the attitudes of engineering faculty toward students with LD? (b) What are the attitudes of engineering faculty for providing accommodations for students with LD?

5. What willingness to try new pedagogical approaches to improve learning for all students, including students with LD is demonstrated by engineering faculty members?

Pilot Study

Demographic survey items that had not been used previously were piloted with a small group of faculty at a college unrelated to the study. The purpose of this pilot was to verify that items were presented such that faculty had no difficulty in responding appropriately. In addition, the pilot allowed determination that relevant pedagogical strategies had been included in the survey item and to confirm that data regarding pedagogy could be accurately collected with this item. In addition, comments were welcomed, but not required, by participants in the pilot study. Results of the pilot led to adjustments in formatting these items. Further, comments by pilot participants resulted in the incorporation of an assessment strategies item as well as a pedagogical strategies item.

Accordingly, the demographic and knowledge components of the survey instrument to be used in this study reflect results of the pilot. One question asks faculty members to identify their educational background related to teaching; another question asks faculty to rank the pedagogical strategies they employ in their instruction; and a

third asks faculty to rank the assessments they utilize for students in their classrooms (see items 5 & 7, Appendix A).

Participants and Setting

Engineering Faculty members that represent California engineering programs that have and have not been members of the Engineering Education Coalition (EEC), funded by the National Science Foundation from 1990-2005, were solicited for participation in the study. The engineering programs invited to participate have been accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology which promotes a project-oriented engineering education emphasizing student development of design skills. In addition, faculty from two EEC institution were solicited to reflect engineering faculty that may have focused on an innovative curriculum with the goal of increasing interest and retention among students that include women and underrepresented minorities.

Engineering programs from three California universities were originally invited to participate in this study. Invitations were expanded to total eight engineering programs before completion of the study. Two of the eight invited institutions belonged to the Synthesis Coalition of the EEC during the years 1990 – 2001 (foundationcoalition.org).

Two of the invited engineering programs represented large, private research institutions with reported undergraduate student populations from 7,900 to nearly 17,000 and graduate student populations from 8,500 to over 18,000. Undergraduate studies at these institutions include biological sciences, chemistry, physics, mathematics, and

engineering. Engineering faculty representation in these two institutions total nearly 600 faculty members.

Four engineering programs from public state universities were invited to participate in this study. These universities lie in suburban environments from 20 to 90 minutes from a large southern California city. Undergraduate student populations in these universities range from 19,000 to 35,000 students, while these universities reported graduate student populations to range from 1,700 to 2,100 students. Engineering teaching faculty employed by these universities range from 55 to 130 faculty members.

Two small private institutions were also invited to participate in this study via contact with a dean or a chair of their engineering programs. These institutions are located in suburban settings with reported undergraduate populations from 750 to nearly 1,000. One of these institutions reported graduate student populations of over 1,250 students. Engineering faculty members employed by these two schools totaled 115.

Instrumentation and Procedures

An instrument that combines demographic data collection, including pedagogy and assessments used by engineering faculty members, with survey questions used by permission from Murray, Wren, and Keys (2008) served for acquisition of data and provided insight to the research questions under consideration. Demographic data collected included gender, faculty status, engineering discipline, previous academic experience within the discipline of education regarding teaching or educational practices, and pedagogical and assessment methods currently used (Appendix A). Effort was made

to present prompts for these demographic data with the least judgmental perspective to improve the likelihood of uncensored responses by participants.

Efforts to determine faculty implementation of metacognitive strategies were made through an open-ended question that asked in what way the instructor encourage development of his or her students' metacognitive skills. In addition, evidence regarding whether faculty make metacognitive strategies a priority in the classroom was gleaned from the ranking of assessment methods used as well as assessment strategies used (see item 6, Appendix A). For example, faculty who utilized student reflections after topic presentations or who required students to maintain a course-related journal, would be displaying evidence that one of the priorities of the course was that students reflect on and think about how they learn—hallmarks of metacognition. There was another open-ended survey question designed to assess the faculty member's level of student-centeredness. This question asked the participant to detail how student interests and prior course-related experiences were determined.

Items from the survey by Murray et al. (2008) were categorized by those authors into 12 factors and their internal consistency reliabilities determined (see Appendix B). These factors were used to uncover faculty members' knowledge of and attitudes toward learning disabilities and their willingness to provide accommodations and adjust pedagogy as needed by students with LD (see instrument sample in Table 3-1 & Appendix B). Participants rated the 36 items of this survey with a Likert-style scale which ranged from 1 (Strongly Disagree) to 5 (Strongly Agree).

Table 3-1

Sample Survey Factors showing single instrument item (Murray, Wren, & Keys, 2008)

***Factor 1**: Willingness to Provide Major Accommodations* I am willing to grade students with verified learning disabilities on a different curve.
***Factor 2:** Willingness to Provide Exam Accommodations* I am willing to change the method of responding to exams for students with verified learning disabilities.
***Factor 3:** Fairness and Sensitivity* Providing teaching accommodations to students with verified learning disabilities is unfair to students without.
***Factor 4**: Knowledge of LD* I know what the term "learning disability" means.

Data Collection

Prior to any data collection, the research design received approval by the university's Institutional Review Board (IRB). The first step in the process was completion of the on-line training sessions. Following the training and the defense of the research proposal, IRB was contacted for assessment of this research. Access to e-mail distribution for engineering faculty was made through the dean or other recommended contact person from each engineering program. Assurance was provided to participants regarding anonymity. The survey tool to be used tracked participants' IP (Internet Protocol) addresses only, so participant identities were not made available to the researcher. After completion of these steps, data collection ensued. A follow-up message via e-mail served to remind and encourage faculty participation, when necessary, two weeks following the initial request.

The link to a Qualtrics survey tool was electronically delivered to all faculty in engineering at the selected institutions during the 2011-2012 academic year. The

Qualtrics survey tool, available for use by members of the University of Southern California community, allowed preparation of a customizable electronic survey that was not blocked by pop-up blockers (USC, 2011). In addition, this survey tool coded data for use in the statistical program for the social sciences entitled SPSS.

Analysis

The fundamentally evaluative question of whether faculty in engineering were responding to the needs of college-level students with LD guided the study. Faculty were grouped according to their associated institution's prior membership or not in the EEC coalitions. The innovative philosophy of the coalitions may have led to engineering programs with more open attitudes toward diverse students, including students with LD. The faculty group from the coalition membership institution had the possibility of representing what McEwan and McEwan (2003) call a counterfactual. The counterfactual would represent faculty with a different philosophical perspective from what may be expected to more typical among engineering faculty members.

In order to interpret resulting data in support of the fundamental evaluative question, the differences among the 12 factors of faculty attitudes between the two types of engineering programs (prior membership or not in EEC coalitions) were to be determined with a multivariate analysis of variance (MANOVA). In addition, MANOVA was to be used to determine the differences between the attitude factors, representing dependent variables, and gender, rank, engineering discipline, and teaching education experience, representing independent variables. However, the small response size resulted in skewed data and the violation of the assumption of normality;

consequently, this analysis could not be completed. The mean scores for each category from each engineering program and for the combination of engineering programs were ascertained to determine the level of positive or negative faculty response overall for any specific survey items.

Frequency distributions of pedagogical and assessment rankings were compiled for each engineering discipline group in each institution. In addition, kurtosis and skew were ascertained to check for normal distributions. The goal of performing a one-way ANOVA to determine whether rankings of pedagogical and assessment practices differed between the two independent samples of engineering discipline faculty groups, EEC coalition member faculty and non-member faculty was not met, due to a low level of responses. In addition, use of the General Linear Model (GLM) analysis of variance to examine pedagogical and assessment practice rankings of the two types of engineering program was not used as a result of low response level.

Correlation coefficients were employed to determine how categories of attitudes correlate to each other within results from each engineering program. Categories showing these connections to other factors sought to improve the understanding of faculty perceptions and attitudes about students with LD. Examination of correlations between the two different types of engineering programs in the study, had the potential of offering an opportunity to recognize any broad perceptual and attitudinal trends among engineering faculty.

Murray, Wren, and Keys (2008) tested items in each of the 12 factors for internal consistency reliability. Their resulting coefficient alphas ranged from highs of .81, .89,

and .84 for Factor 1 (Willingness to provide major accommodation), Factor 7 (Resource constraints), and Factor 10 (Personal action: Inviting disclosure), respectively, to lows of .65 for both Factor 3 (Fairness and sensitivity) and Factor 4 (Knowledge of learning disabilities). Internal consistency coefficient alpha values for all other categories ranged from .70 to .75. The authors selected only those categories with Eigenvalues greater than 1.0 for inclusion in the instrument, described by Brown (2001) as the value most commonly associated with categories worth analyzing.

Open-ended questions were analyzed quantitatively as presence or absence. In addition, these data were examined qualitatively through inductive reasoning for categories and themes present among the responses (Patton, 2002).

Limitations and Delimitations of Study

Studies that use survey instruments report various levels of participation, for example, from 23 % (Murray, Flannery, & Wren, 2008) to 40 % (Vogel, Leyser, Wyland, & Brulle, 1999). A similar participation rate was expected for this study. Low numbers of participants may lessen the significance, or power, of the results (Salkind, 2010).

Low levels of participation, even if expected, lessen any generalizability of results, as does the fact that the institutions incorporated into this study were from California settings only. Care must be taken in applying results to other academic settings and geographical regions, under the best levels of participation, because institutions, faculty present, and students attending them are not identical to those from various other settings. Additionally, with the typical low levels of participation, it likely

cannot be determined if the resulting faculty responses represent completely the perceptions and opinions of the entire faculty at any institution.

Another limitation envelops the evidence for pedagogical and assessment practices within the classroom, including faculty use of metacognitive strategies. The instrument used to garner faculty pedagogical and assessment practices requests ranking of the top five practices used. Little evidence was obtained for additional instructional and assessment practices, or any other strategies incorporated by engineering faculty. In various classroom settings, under guidance of certain faculty members, strategies beyond the top five may be relevant.

This was a correlational study, so it has been used for evaluative purposes, but did not demonstrate any causality between faculty approaches in the classroom and limited academic success in engineering for students with LD. In addition, the study utilized purposeful sampling focused on engineering faculty, rather than a random sampling of all faculty participants. Patterns observed in the results warranted reflection, but did not demonstrate any causality or guarantee that any pattern of results possessed broad meaning.

CHAPTER 4: RESULTS

The study asked what knowledge was held as well as what pedagogical and assessment approaches were practiced by college-level engineering faculty members. In support of these research questions the study sought to determine the attitudes held by engineering faculty toward students with learning disabilities (LD) and how engaged these faculty were in improving course content access to students with LD. Finally, the study endeavored to determine whether faculty made any effort to incorporate pedagogical approaches that would aid student development of metacognitive strategies.

There were three assumptions that constituted the foundation of this quantitative study. The reports that academic success for students with LD has been declining in the sciences, mathematics, and engineering (e.g., Vannest et al., 2009) were accepted and represented the motivation for a pedagogical study of college-level sciences, mathematics, and engineering. Further, it was assumed that faculty from the sciences, mathematics, and engineering wanted all their students to succeed academically and that faculty from these disciplines held empirical research in high regard, as indicated in Colbeck's (1998) research on faculty integration of research and teaching.

Colbeck (1998) provided evidence that faculty from the natural sciences, in particular, valued the empirical research process. The work supported the expectation that faculty from the STEM disciplines would show willingness and be interested in changing pedagogical approaches that would lead to improved academic success for students, including those with LD. However, with a few individual or programmatic exceptions (e.g., Akerson et al., 2002; Grumbine et al., 2005), most faculty from these

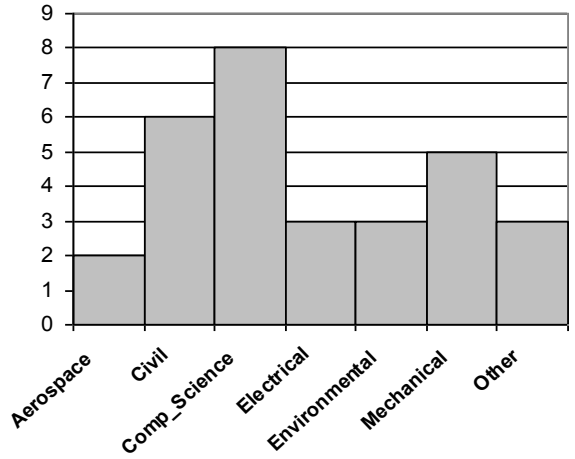
disciplines have used the pedagogical strategies they experienced as students, usually the traditional lecture format (Baldwin, 2009).

Fundamental Study Results

Eight secondary institutions with engineering programs were solicited for this study. Four institutions allowed distribution of the link for the anonymous survey instrument to engineering faculty members on their campuses. Response levels ranged from two to just over 10.5% of the engineering faculty employed by each of the institutions that approved distribution of the study's survey instrument. Distribution of faculty ranking across all participants (n=30) was fairly even among the rankings. Full professors accounted for 23.3%, associate professors for 26.7%, assistant professors for 26.7%, and lecturers for 23.3%. Sixty-three percent of participants were male and 37% were female faculty members from disciplines incorporated into the engineering programs from the institutions that participated in this study. The specific engineering disciplines represented encompassed aerospace, chemical, computer science, civil, electrical, environmental, industrial, and mechanical engineering (Figure 4-1).

Figure 4-1

Frequencies of Participants' Engineering Disciplines



From 24 to 27 of the 30 participants completed items related to the survey component related to faculty knowledge and attitudes regarding students with LD, used by the permission of Murray, Wren, and Keys (2008). Their survey instrument was designed to ascertain faculty knowledge and attitudes regarding students with LD, according to twelve survey factors identified in Table 4-1. Results of these survey factors were combined with demographic data collected for gender, faculty ranks, engineering discipline, previous academic experience within the discipline of education regarding teaching or educational practices as well as determination of the pedagogical and assessment methods currently used (Appendices C-F). In addition, two prompts offered participants the opportunity to provide methods they use to learn about student backgrounds and to identify support for student development of metacognitive skills.

Table 4-1

Survey Factor Knowledge and Attitudes Components

Factor	Component*
1	Willingness to provide major accommodations
2	Willingness to provide exam accommodations
3	Fairness and sensitivity
4	Knowledge of learning disabilities
5	Willingness to personally invest
6	Willingness to make teaching accommodations
7	Resource constraints
8	Performance expectations
9	Disclosure and believability (negative construct)
10	Personal action: Inviting disclosure
11	Personal action: Insufficient knowledge (negative construct)
12	Personal action: Providing accommodations

*Used by permission (Murray et al., 2008)

Correlations among the survey factors were determined (Table 4-2). Faculty members' fairness and sensitivity (Factor 3) was found to have the strongest correlation with faculty expectation of student success at the university level ($p<.01$). As seen in Table 3, other factors also correlated significantly.

Table 4-2

Survey Factor Correlations Matrix

	1	2	3	4	5	6	7	8	9	10	11	12
1												
2	.354											
3	.337	*.422										
4	-.176	-.095	.320									
5	.062	.204	.354	.188								
6	*.436	**.591	.297	-.019	.247							
7	.222	.166	-.152	*-.438	*-.419	-.005						
8	.264	*.418	**.744	.295	.231	.117	-.022					
9	.000	.176	.311	.112	.059	.205	-.274	.122				
10	.047	-.060	.134	-.108	-.012	-.358	.057	.007	-.231			
11	-.214	.196	.037	.196	.321	.095	**-.663	-.109	.079	.147		
12	.144	**.673	**.561	.281	.362	*.494	.024	*.476	.294	.077	.274	

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

** Correlation is significant at the 0.01 level (2-tailed).

Assessment of normality was ascertained for the dependent variables: pedagogical and assessment methods, and the faculty knowledge and attitudes survey factors. Most dependent variables were found to have normal distributions. The pedagogical method, lecture, as well as the assessment method, exams, did demonstrate both significant skewness and significant kurtosis. In addition, the survey factor that examined the presence of insufficient knowledge about providing accommodations for students with LD (Factor 11) demonstrated significant skewness and kurtosis.

Research Question 1

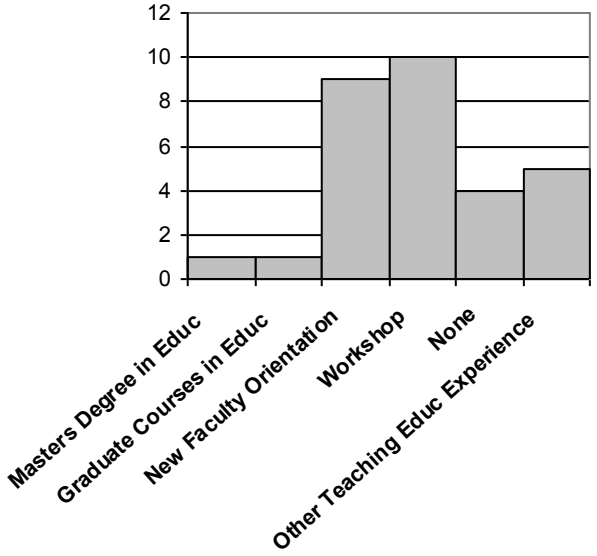
The first research question asked what educational backgrounds engineering faculty members possessed that provide them with knowledge of learning theory and pedagogical methods. Associated with the question of the educational backgrounds of

engineering faculty was the specific question asking whether faculty members from engineering disciplines had taken courses in education.

Among participants, 63.3% of engineering faculty had attended a workshop or an orientation program related to teaching as a new faculty member (see Figure 4-2). Two individuals in the study (6.6%) had participated in courses or held a graduate degree in education. The remaining participants identified other teaching related experiences, such as serving as a teaching assistant during graduate school, or had no experience with any training related to teaching education.

Figure 4-2

Frequencies of Teaching Educational Experiences



The mean score of the survey factor (Factor 4) representing faculty knowledge of learning disabilities (Murray et al., 2008) was 3.61, where a score of one represented "Strongly Disagree" and a score of five represented "Strongly Agree." The two items from which survey factor four was composed revealed that all engineering faculty

participants reported knowing the definition of learning disabilities (see survey items in Appendix A). No participant reported strong agreement to familiarity with section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act (1990) and their implications for students with LD. Of the responses to this survey item, 33.3% reported disagreement or strong disagreement to familiarity with section 504 and its student implications.

Faculty knowledge of learning disabilities (Factor 4) was also found to be significantly negatively correlated ($p<.05$) with the faculty members' perceptions that their ability to provide accommodations for students with LD was affected by time constraints and demands of faculty responsibilities (Factor 7).

Research Question 2

The second research question in this study asked what specific pedagogical and assessment approaches were employed by engineering faculty members. Pedagogical methods identified specifically consisted of lectures, in-class questioning, small group discussion, universal design for learning (UDL), and other, through which participants had the opportunity to specify the pedagogical methods used, such as in-class assignments and student presentations. Assessment methods specified in the study's survey were student reflections, student journals, quizzes, exams, research papers, essays, and other, again allowing for a participant to specify other assessment methods used. The other assessment methods identified included laboratory reports and homework.

Results showed that the pedagogical method most frequently ranked first or second by engineering faculty participants (82.1%) was the lecture (Table 4-3). Lecture responses demonstrated a skewed distribution, due to its high ranking by participants.

In-class questioning was ranked first most among the remaining pedagogical methods. However, when first and second rankings were combined, in-class questioning resulted in 36% of participants (9 responses) who utilized this method, while 58% (14 responses) utilized small group discussions. A total of ten participants ranked UDL among their pedagogical methods of choice, although two other participants disclosed that the term UDL was unfamiliar to them. No correlations were found among any of these normally distributed pedagogical methods and faculty ranks, teaching education experience reported by faculty, or gender.

Table 4-3

Frequencies of Responses for each Pedagogical Method Used

(1=Most used pedagogical method; 5=Least used pedagogical method)

Rankings:	**1**	(%)	**2**	(%)	**3**	(%)	**4**	(%)	**5**	(%)	Totals	M	SD
Lecture	20	(71.4)	3	(10.7)	1	(3.6)	2	(7.1)	2	(7.1)	28	1.68	1.28
In-class Questioning	4	(16.0)	5	(20.0)	12	(48.0)	4	(16.0)	0	(0.0)	25	2.64	.95
Small Group Discussion	2	(8.3)	12	(50.0)	3	(12.5)	6	(25.0)	1	(4.2)	24	2.67	1.09
UDL	1	(10.0)	2	(20.0)	3	(30.0)	1	(10.0)	3	(30.0)	10	3.30	1.42
Other	1	(12.5)	3	(37.5)	1	(12.5)	3	(37.5)	0	(0.0)	8	2.75	1.17

Ninety-six percent of participants ranked the assessment method, exams, as their primary or secondary choice (Table 4-4). Distribution of responses to exam displayed skewness, due to the extensive high ranking by participants. No correlations were found

among any of the other assessment methods, which were normally distributed, to faculty ranks, teaching education experience reported by faculty, or gender.

Table 4-4

Frequencies of Responses for each Assessment Used

(1=Most used assessment; 5=Least used assessment)

Rankings	**1**		**2**		**3**		**4**		**5**		Totals	M	SD
Exams	16	(64.0)	8	(32.0)	0	(0.0)	1	(4.0)	0	(0.0)	25	1.44	.71
Quizzes	2	(11.8)	7	(41.2)	5	(29.4)	3	(17.6)	0	(0.0)	17	2.53	.94
Research Paper	1	(6.7)	3	(20.0)	6	(40.0)	4	(26.7)	1	(6.7)	15	3.07	1.03
Reflections	2	(18.2)	3	(27.3)	3	(27.3)	2	(18.2)	1	(9.1)	11	2.73	1.27
Other	7	43.8)	5	(31.3)	2	(12.5)	1	(6.3)	1	(6.3)	16	2.00	1.21

Research Question 3

The third research question sought to determine whether engineering faculty members encouraged their students' development of metacognitive skills. Twelve participants (40%) responded to the open-ended prompt, "In what ways do you encourage your students to learn and/or reflect on how they learn, if applicable. Such encouragement reflects support for the development of your students' metacognitive skills." Responses fell into four general categories, presented in Table 4-5. In addition, the use of journals as an assessment tool by five engineering faculty participants served as an element of support for encouraging student development of metacognitive skills.

Table 4-5

Participant responses—Efforts for Student Development of Metacognitive Skills

(N=12)

Response Category	Responses
Student Reflection	2
Student Peer Problem-solving	3
Activities for Students to Learn-by-Doing	6
No Knowledge	2

Eighteen participants responded to the open-ended prompt asking how faculty members become familiar with student backgrounds. The prompt asked, "How do you learn about your students' backgrounds and previous course-related experiences, if applicable?" A summary of identified themes from responses appears in Table 4-6.

Table 4-6

Participant responses—Effort toward Learning Students' Backgrounds

(N=18)

Response Category	Responses
Assessment/Survey/Questionnaire at start of Term	8
Informal Discussions/Questioning	8
Student-initiated Discussions	2
Determination of Pre-requisite Completion	6

Research Questions 4 (a) and (b)

The fourth research questions in this study asked what attitudes were held by engineering faculty members toward students with learning disabilities and toward providing accommodations for this population of students. Results that supported this research question were taken from the survey developed by Murray et al. (2008) in which participants respond from 1 (strongly disagree) to 5 (strongly agree).

Among the attitude survey's highest mean scores was the mean from the factor addressing the expectation of student success at the college level (Factor 8, M=4.192), which focused on faculty belief that students with LD can compete and be successful college-level students (Table 4-7). Survey factor eight also displayed a highly significant correlation ($p < .01$) with faculty members' sensitivity and fairness toward students with LD (Factor 3).

Table 4-7

Means—Knowledge and Attitudes Factors (1=strongly disagree to 5=strongly agree) (Knowledge and Attitudes Survey, Murray et al., 2008)

Survey factors:	1 Willingness Major Accomm.	2 Willingness Exam Accomm.	3 Fairness & Sensitivity	4 Knowledge of LD	5 Willingness Personal Investment	6 Willingness Provide Teaching Accomm.
M	2.840	3.968	3.907	3.611	4.220	4.395
N	25	25	25	27	25	27
SD	.3367	.52814	.39698	.65535	.64679	.57018

Survey factors:	7 Resource Constraints	8 Performance Expectations	9 Disclosure & Believability	10 Inviting Disclosure	11 Insufficient Knowledge	12 Providing Accomm.
M	2.333	4.192	3.773	2.820	3.479	4.060
N	24	26	25	25	24	25
SD	.89281	.58441	.81491	1.36839	.81400	.69702

Participants' scores for fairness and sensitivity to students with LD (Factor 3) also correlated significantly ($p < .01$) with the faculty members' previous experience at providing accommodations for students with LD (Factor 12). In addition, the survey factor addressing faculty members' expectations that students with LD can be successful at the university level (Factor 8) correlated significantly ($p < .05$) with faculty members' previous experience at providing accommodations for this student population (Factor 12).

Two engineering faculty members who declined to complete the survey volunteered that they believed they had no previous experience teaching students with LD.

Research Question 5

Aligned with the previous research question, the fifth research question asked how willing engineering faculty members were to provide accommodations to students with LD. Several survey factors addressed faculty willingness to provide accommodation and provide support for students with LD.

According to the language used by Murray et al. (2008), the survey factor labeled willingness to provide exam accommodations (Factor 2) showed correlation with a suite of other factors (see Table 4-8). Scores from Factor 2 correlated significantly ($p<.01$) with willingness to provide teaching accommodations (Factor 6), with scores for fairness and sensitivity to students with LD (Factor 3; $p<.05$), with the expectation of success for students with LD at the college level (Factor 8; $p<.05$), and with the participants' previous experience with providing accommodations for students with LD (Factor 12; $p<.05$). In addition, the scores for having previously provided accommodations for students with LD correlated significantly with willingness to provide teaching accommodations (Factor 6; $p<.05$).

Table 4-8

Survey Factor Correlations Related to Faculty Willingness

	2	3	6	8	12
2					
3	*.422				
6	**.591	.297			
8	*.418	**.744	.117		
12	**.673	**.561	*.494	*.476	

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

** Correlation is significant at the 0.01 level (2-tailed).

Willingness to provide exam accommodations (Factor 2) resulted in one of the highest mean scores, compared with mean scores for other factors. Willingness to personally invest (Factor 5) and the willingness to make teaching accommodations (Factor 6) were the two survey factors that showed the highest mean scores, however. Further, faculty willingness to personally invest in support of students with LD (Factor 5) negatively correlated at a significant level with faculty members' perception that job responsibilities and time limitations affected their ability to provide accommodations for students with LD (Factor 7).

CHAPTER 5: DISCUSSION

This study provided potential indicators of attitudes and educational backgrounds of engineering faculty members regarding students with learning disabilities (LD). In addition, the study provided evidence of how cognizant engineering faculty were concerning student development of metacognitive skills. The study sought to offer a basis for future research about engineering faculty in relation to their students with LD.

Engineering Faculty Knowledge and Pedagogical Methods

Knowledge. It can be concluded from results of this study that the increase in knowledge increases openness and willingness for providing necessary and valid accommodations for students with LD. While discipline-specific education is essential for teaching at the college level, no educational preparation courses are required. The little background in education possessed by engineering faculty members in this study illustrate this lack of background in the field of education that has been reported for college-level educators from many disciplines (Flick et al., 2009). The majority of engineering faculty participants (63.3%) had attended a workshop or an orientation program that centered on teaching. Among the faculty members in engineering disciplines who took part in this study, very few participants (6.6%) have completed courses in the field of education.

While most participants reported some familiarity with section 504 of the Disabilities Act and its implications for students with LD, no participant reported strong familiarity. That 33.3% of participants reported disagreement or strong disagreement to familiarity with section 504 and its student implications offers evidence that

improvement is needed for strengthening engineering faculty knowledge of the law surrounding support for students with LD.

The negative correlation between Factor 4 (knowledge of LD) and Factor 7 (resource constraints), supported by the high mean score of Factor 4 and enhanced by the low mean for Factor 7 from the participant responses, offered evidence to support increasing faculty knowledge about teaching students with LD. An increased faculty knowledge and awareness about learning disabilities would presumably lead to a diminished faculty belief that providing accommodations for students with LD is limited by time and job constraints.

Pedagogy. Results from both the ranking of pedagogical methods and assessments employed did not offer surprises. As might have been expected (Baldwin, 2009) the pedagogical method most commonly used by engineering faculty participants was the lecture. Projects, design reports, and laboratory exercises were mentioned by nine participants as pedagogy as well as assessment approaches, in line with the project-based engineering instruction described by Dym et al. (2005), but the majority of participants identified the lecture as the first (71.4%) or second (10.7%) pedagogical choice. These facts align with the reports that most college faculty teach in the manner they were taught (Halpern & Hakel, 2002).

The highly ranked lecture and exam pedagogical and assessment methods, respectively, do not offer optimism that the principles of universal design for learning (UDL) are supported by college-level engineering instructors. Distribution of ranking data from lecture and from exam survey items did not exhibit normal distributions

because the highly ranked participant responses in these two survey items skewed these data.

Misconceptions addressed by pedagogy. No question on the study survey directly addressed how or if instructors addressed misconceptions that student often possess prior to enrollment in a course (Modell et al., 2005). A few participants offered evidence that some faculty were seeking to determine student misconceptions. One response specifically stated that he or she provided "'refresher' lectures" for student weaknesses that were identified. Another participant shared that he or she addressed students' feelings about assessments during discussions about student performance in order to determine whether the methods used in the course were reaching students at their level of preparedness. Such methods used by these two faculty participants have the possibility of addressing student misconceptions when they are present. Of the 18 participants who responded to the open-ended prompt, however, most did not provide responses that demonstrate any concern about student misconceptions. The emphasis in one third of the responses on checking prerequisite requirements indicated that participants who provided these responses expected that meeting the requirements for a course meant that students were prepared for that course's content.

Student acclimation to the college setting. According to Calhoun (2003), one of the concerns for many students with LD is acclimation into the college classroom. It has been articulated (McGlaughlin et al., 2005) that greater knowledge of the student by faculty members increases comfort level and classroom acclimation for students with LD.

Most of the 18 participants who responded to the open-ended question that asked how faculty members learned about student backgrounds offered evidence of willingness to learn about students. Surveys and questionnaires at the start of a term as well as informal discussions with students indicated faculty interest in student backgrounds. Two additional respondents were apparently willing to learn about student backgrounds, but only if discussions were initiated by the student. Less personal yet and, therefore, likely less beneficial to the student are the checks that are solely focused on students' meeting pre-requisite requirements for a course. Even more of a concern was the one response in which the faculty member suggested he or she could not "even learn their names" due to the large class size. Support for a student with LD may be insufficient in such a classroom setting.

Faculty Misconceptions Regarding Students with LD

There appears to be less clarity among faculty members in this study regarding accommodations for teaching than for providing accommodations for testing. Although a majority (79.2%) of engineering faculty participants reported possession of the knowledge necessary to provide exam accommodations, only 45.9% of participants reported sufficient knowledge needed for providing teaching accommodations. The lack of faculty clarity parallels the lack of knowledge apparent regarding UDL in which pedagogical methods ideally allow students with any disabilities to access the course content via multiple methods of presentation and multiple methods of assessment.

Ten participants ranked UDL as a pedagogical method they utilized, but only one participant ranked it first. Two participants shared their lack of familiarity with this

pedagogical method. The results of this study demonstrate that even though a majority of participants appeared to possess attitudes in support of students with LD, their combination of weak responses regarding teaching accommodations and an overemphasis on lectures and exams show that students with LD would be better served if faculty received additional education for teaching methods for a diverse student population.

One possible misconception faculty members may possess is a lack of recognition that students with LD are enrolled in their classes. It cannot be declared with certainty that the faculty who avowed no previous experience teaching students with LD were responding factually. At least two possible rationales may be considered to explain these faculty perceptions.

The first consideration is that a student with LD may feel concern faculty members would lower their expectations for the student's success in the college setting or receive an advantage through an accommodation over other students (Casey, 2007). Such a student may avoid accommodation requests, particularly in light of the connection between classroom attitudes and success for students with LD (May & Stone, 2010). The course-related faculty member, therefore, may not have awareness of the presence of students identified to have learning disabilities.

The second possible explanation for why an engineering faculty member may have no experience in teaching students with LD may reflect a system-level problem. There is the possibility that students with LD interested in the study of engineering disciplines or the study of many other STEM disciplines may not have received sufficient support in their previous schooling for progress into the study of engineering at the

university level, as addressed by Schuster and Carlsen (2009). This possibility was addressed in the report from Vannest et al. (2009) that conveyed that students with LD have generally not been well served in college-level STEM areas of study.

Development of Student Metacognitive Skills

Results from this study offer evidence of a need for more faculty development of the principle of metacognition, particularly as it serves students with LD. Chowdhury (2004) reported that development of metacognitive skills supported academic success for engineering students, but metacognition is often particularly important for students with LD (Hall & Webster, 2008). The extent of the encouragement offered to students by engineering faculty could not be strongly estimated due to the lack of participant responses to the open-ended prompts. The larger proportion of those who did respond (n=9) offered methods that encouraged students to work together or to "learn by doing," as one participant termed the method used. These strategies were presumed to increase a student's awareness of how he or she learns. The learning by doing approaches harmonized with Grumbine and Alden's (2006) "principles-to-practice" examples for teaching students with LD and support the priority placed on metacognitive skills by many faculty participants in this study.

Two participants identified student reflection as their method of encouragement. Student reflection is traditionally a prominent method of assisting student to develop metacognitive skills (Grumbine & Alden, 2006). However, another two participants stated that they had no knowledge of the term, metacognition. A larger sample size may

have provided sufficient responses to discern how widely engineering faculty are encouraging student development of metacognition in practice.

Attitudes and Willingness toward Accommodating Students with LD

Faculty awareness of and support for students with LD was, not surprisingly, linked to their attitudes toward this population of students. Correlations from a suite of survey factors supported this conclusion. The survey factor addressing previous faculty experience at providing accommodations for students with LD (Factor 12) correlated significantly with faculty expectation for student success in the college setting (Factor 8) and with their willingness to provide accommodations in teaching for students with LD (Factor 6). In addition, Factor 12 demonstrated a highly significant correlation with faculty willingness to provide exam accommodations (Factor 2) as well as with faculty sensitivity and sense of fairness for students with LD (Factor 3).

Further strengthening the importance of faculty attitudes toward support for students with LD is the significant correlation between faculty sense of fairness (Factor 3) and their willingness to provide exam accommodations. In addition, the correlation between faculty sensitivity and fairness was found to be highly significant to faculty expectation of success at the college level for students with LD.

The first survey factor labeled “Willingness to Provide Major Accommodations” (Murray et al., 2008) resulted in one of the lowest mean scores and low correlations with other willingness and attitudes survey factors. This result may appear to contradict the apparent willingness of the participant population demonstrated by strong correlations among other willingness survey factors. However, the specific accommodations

addressed by the survey items comprising Factor 1 offer a possible explanation for the disparity. Many faculty members may consider survey item content, such as substitution of an alternative course for a required course or creation of a different grading curve for students with LD, to be matters of academic integrity. Additional content addressed by items within Factor 1, such as allowing extra credit and the reduction of course reading load for students with LD, may also be highly charged topics for many instructors.

The two factors with highest mean scores, the willingness to personally invest (Factor 5), and the willingness to make teaching accommodations (Factor 6), offered evidence that engineering faculty who participated in this study were highly willing to support students with LD. Also, among the survey factors with a high mean score was the willingness to provide exam accommodations (Factor 2). This factor specifically addressed the provisions of extended time, changes to testing location, and use of technology, for example. Scores from participants in this study demonstrated high willingness to provide such testing accommodations.

Results indicated that faculty participants in this study demonstrate less confidence regarding teaching accommodations than they display regarding exam accommodations. A faculty member's willingness to provide teaching accommodations (Factor 6) did not demonstrate a significant correlation with the survey factor addressing faculty sensitivity and fairness (Factor 3) or with the survey factor related to faculty expectations for successful student performance at the college level (Factor 8). Nevertheless, the survey factor regarding a faculty member's willingness to provide exam accommodations (Factor 2) was significantly correlated to both Factors 3 and 8. While

many instructors may possess experience with providing extended time as an exam accommodation, these same instructors likely have no training or experience in what could constitute a teaching accommodation. An increase in faculty training would be expected to improve faculty understanding and confidence to the diversity of possible teaching as well as exam accommodations that are appropriate for some students with LD.

Limitations of the Study

The participants in this study may represent a subset of engineering faculty members most of whom have an awareness of and an attitude of support for students with LD. Among the responses, for example, 92.6% agreed or strongly agreed that they were sensitive to the needs of students with LD. However, it is not possible to know whether these responses reflected participant desire to respond as they believed they should respond or whether they agreed to participate in large part because they were open-minded and genuinely sensitive to the needs of students with LD.

The internal political concerns with no direct relationship to the study which resulted in the absence of participation from one institution solicited constituted a delimitation of the study. Recognition of the resulting reduced sample size led to invitations to additional engineering programs in California institutions of higher education. In spite of the widespread requests of participation, the incomplete institutional participation limited the data for this study. In addition, the low response levels exhibited by engineering faculty at participating institutions results in an inability to generalize about the results of this study.

Implications for Practice

This study offered evidence to support increased professional development for engineering faculty members. The results supported the premise that some engineering faculty have been utilizing pedagogical methods to improve student access to course content as well as to encourage student development of metacognitive skills. However, these efforts may not be widespread and do not apparently address course accessibility for students with LD.

Future Research

A larger sample of participants from the engineering disciplines must be acquired in future research of the knowledge, pedagogical, and assessment methods utilized by engineering faculty. Consideration must be given to qualitative methods of obtaining this information from the faculty in the engineering disciplines. Methods, such as multiple classroom observations and/or interviews with engineering faculty would likely offer results from a wider sample of faculty members. In addition, qualitative methods would reduce the potential for self-reporting errors that may result from data collection through anonymous surveys and would improve the acquisition of engineering faculty attitudes and willingness of supporting students with LD.

Conclusion

Most of the engineering faculty that participated in this study demonstrated that there seemed to be a willingness to provide support and accommodations for a diverse student population. However, even among this willing group of engineering faculty members, there were few participants that seemed to possess the knowledge of alternative

pedagogical and assessment methods that would make course content more accessible to students with or without LD. Improved faculty development programs to offer training in these alternative methods was regarded to be warranted, as a result of this study.

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APPENDIX A

Demographic and Educational Practice Data

1. Gender: M F

2. Faculty rank: Full Professor | Associate Professor | Assistant Professor | Adjunct Professor | Lecturer

3. Academic Discipline: Aerospace Engineering | Biomedical Engineering | Civil Engineering | Computer Science | Electrical Engineering | Environmental Engineering | Mechanical Engineering | Other:

4. Teaching education experience. Please select the item that reflects your previous educational experience that applied to teaching practices.

   ____ Doctoral Degree in Education

   ____ Master's Degree in Education

   ____ Completion of graduate courses in education

   ____ Participation in teaching orientation program as a new faculty member

   ____ Participation in a workshop applicable to teaching methods

   ____ Attendance to a lecture applicable to teaching methods

   ____ No educational experience specifically focused on teaching practices

   ____ Other, please elaborate:

5. Pedagogical Practices. Each of the following pedagogical approaches has been demonstrated to result in student success. Please select the practices you employ most commonly in your courses ranked from most used (1) to least used (5).

1	2	3	4	5	N/A	Lecture
1	2	3	4	5	N/A	Guided questioning in-class
1	2	3	4	5	N/A	In-class small group activities
1	2	3	4	5	N/A	Universal design instruction (i.e., multiple methods of presentation, assessment, and student expression)
1	2	3	4	5	N/A	Other, please describe: _____

6. How do you learn about your students' backgrounds and previous course-related experiences, if applicable?

_____

7. Assessment Practices. Please select the assessment practices you employ most commonly in your courses ranked from most used (1) to least used (5).

1	2	3	4	5	N/A	Student reflections after topic presentations
1	2	3	4	5	N/A	Student requirement to maintain a course-related journal
1	2	3	4	5	N/A	Frequent quizzes for assessing learning
1	2	3	4	5	N/A	One to four exams per semester to assess learning
1	2	3	4	5	N/A	Research paper for assessing learning
1	2	3	4	5	N/A	Frequent essays for assessing learning
1	2	3	4	5	N/A	Other, please describe: _____

8. In what way do you encourage your students to learn and/or reflect on how they learn, if applicable? Such encouragement reflects support for the development of your students' metacognitive skills,

_____

APPENDIX B

Survey Factors Displayed with Items for Each Factor, Including Chronbach's Alpha (Murray, Wren, and Keys 2008)
(Numbers following each survey item identify the order in which items were presented in the survey, 1-36.)

***Factor 1**: Willingness to Provide Major Accommodations* (α = .81)

I think it would be appropriate to allow a student with a verified learning disability to substitute an alternative course for a required course. (9)

I am willing to allow a student with a verified learning disability to complete "extra credit" assignments. (11)

I am willing to reduce the overall course reading load for a student with a verified learning disability.(12)

I am willing to grade students with verified learning disabilities on a different curve. (22)

If a student with a verified learning disability did not adequately meet the course requirements despite receiving reasonable exam accommodations, I would give him/her the grade s/he earned. (23)

***Factor 2**: Willingness to Provide Exam Accommodations* (α = .72)

I am willing to allow students with verified learning disabilities to tape record. (15)

I am willing to arrange extended time exams for students who have verified learning disabilities. (19)

I am willing to change the method of responding to exams for students with verified learning disabilities. (20)

I am willing to allow students with a verified learning disability to take proctored exams in a supervised location. (24)

I am willing to allow students with verified learning disabilities to use technology (e.g., laptop, calculator, spell checker) to complete tests even when such technologies are not permitted for use during testing. (25)

***Factor 3**: Fairness and Sensitivity* (α = .65)

I am sensitive to the needs of students with learning disabilities. (4)

I believe that I make individual accommodations for students as necessary who have disclosed. (13)

I believe that my overall teaching style permits all students to learn the materials regardless of their individual needs. (14)

I am willing to extend the "due dates" of assignments to accommodate the needs of students with verified learning disabilities. (16)

Providing teaching accommodations to students with verified learning disabilities is unfair to students without (rev). (17)

Providing teaching accommodations to students with verified learning disabilities is unfair to students without (rev). (26)

***Factor 4**: Knowledge of LD* (α = .65)

I am familiar with section 504 of the Rehabilitation Act of 1973 *and* the Americans with Disabilities Act (1990), & implications for students with disabilities in institutions of higher education. (1)

I know what the term "learning disability" means. (2)

***Factor 5**: Willingness to Personally Invest* (α = .75)

I am willing to spend extra time (i.e., in addition to normal office hours) meeting with students with a verified learning disabilities to clarify and/or review course related content. (10)

I am willing to spend extra time (i.e., in addition to normal office hours) helping a student with a verified learning disability prepare for an exam. (21)

***Factor 6**: Willingness to Make Teaching Accommodations* (α = .74)

I am willing to provide students with verified learning disabilities copies of my lecture notes or outlines. (6)

I am willing to provide students with verified learning disabilities with additional time to complete assignments. (7)

I am willing to provide students with verified learning disabilities copies of my overheads and/or PowerPoint presentations. (8)

***Factor 7**: Resource Constraints* (α = .89)

Making adequate teaching accommodations for students with verified learning disabilities in my courses is unrealistic given time constraints and other job demands. (28)

Making adequate testing accommodations for students with verified learning disabilities in my courses is unrealistic given time constraints and other job demands. (30)

***Factor 8**: Performance Expectations* (α = .73)

I believe that students with learning disabilities can be successful at the university level. (3)

Students with learning disabilities are able to compete academically at the university level. (5)

***Factor 9**: Disclosure and Believability (*Note: This factor is negatively constructed*)* (α = .70)

I believe that students use learning disabilities as an excuse when they are not doing well in my class. (18)

I find that students with learning disabilities wait to talk to me until they are not doing well in the class and then it's too late to provide appropriate accommodations. (35)

I find that students with learning disabilities wait to talk to me until they are not doing well in the class and then I find it hard to believe that they really have a disability. (36)

***Factor 10**: Personal Action: Inviting Disclosure* (α = .84)

I include a statement in my syllabus inviting students with learning disabilities to discuss accommodations with me. (33)

I make a statement in class inviting students with learning disabilities to discuss accommodations with me. (34)

***Factor 11**: Personal Action: Insufficient Knowledge* (Note: This factor is negatively constructed) (α = .74)

Currently, I do not have sufficient knowledge to make adequate teaching accommodations for student with learning disabilities in my course(s). (27)

Currently, I do not have sufficient knowledge to make adequate testing accommodations for student with learning disabilities in my course(s). (29)

***Factor 12**: Personal Action: Providing Accommodations* (α = .71)

I have had students with LD in my course(s) and have provided teaching accommodations. (31)

I have had students with LD in my course(s) and have provided testing accommodations. (32)

APPENDIX C

Engineering Faculty Rankings of Pedagogical Methods Used
(1=Most used pedagogical method; 5=Least used pedagogical method)

Participant	Lecture	In-class Questions	Small Groups	UDL	Other 1	Other 2
1	1	2			3	4
2	1	3	2		4	
3						
4	1	3	2			
5	1	2	3			
6	2	1	3		4	
7	1	3	2	4		
8	1	2				
9	1	4	2	3		
10	1	1				
11	5	1				
12	1	3	2			
13	1	3	4	2		
14	1	3	4	2		
15	1	3	4		2	
16	1		3		2	
17	1		4		2	3
18	1	1	2	5		
19	1	3	2		4	
20	2	3	1			
21	2		1			
22	1	3	2			
23	1	3	2	5		
24	1	2	2			
25	4	4	4	5		
26						
27	1	2	4	3		
28	5	4	2	3		
29	3	4	5		1	2
30	4	3	2	1		

APPENDIX D

Engineering Faculty Rankings of Assessment Methods Used

(1=Most used assessment; 5=Least used assessment)

Participant	Reflections	Journal	Quizzes	Exams	Research Paper	Essays	Other
1				2	3		1
2	3		4		1	2	5
3							
4			1	2			
5			2	1	3		
6			4	2	3		1
7				2			1
8			2	1			
9	2	4	3	1	5		
10			2	1	4	3	
11			2	1			
12	3			1	4		2
13	1		3	2	4		
14	4	3		1	2		
15	5	4	1	2			3
16				1			2
17			3	1			2
18	4	5	3	1	2		
19			2	1			3
20							1
21	1		3	4			2
22			2	1			
23	3		2	1			4
24				1	2		
25	2	5	4	1	3		
26							
27	2				4	3	1
28				1	3		2
29				2			1
30				2	3		1

APPENDIX E

Engineering Faculty Responses Attitude Survey Factor 1 through Survey Factor 5
(from Murray, Wren, and Keys, 2008)
(1=Strongly Agree; 5=Strongly Disagree)

Factor 1					Factor 2					Factor 3*						Factor 4		Factor5	
2	2	2	2	2	4	4	2	4	2	4	4	4	4	2	2	4	4	4	4
1	3	2	3	2	4	4	4	3	1	4	4	4	2	4	2	3	4	4	4
3	1	3	1	3	5	5	4	5	1	5	4	4	4	2	2	3	5	4	4
4	2	2	2	2	2	4	2	4	2	4	4	3	2	2	2	4	4	4	4
3	3	3	3	3	5	4	2	4	3	4	5	4	5	3	3	3	4	4	4
2	3	2	3	2	5					4	5	5	2			4	3	3	
3	3	3	3	3	4	4	3	4	3	4	4	4	4	3	3	2	3	4	4
3	3	3	3	3	4	4	3	4	4	4	3	4	3	2	2	4	4	4	4
3	3	3	3	3	5	5	4	5	4	4	4	3	4	3	3	1	3	4	4
3	4	2	4	2	4	4	4	4	4	4	4	4	2	2	2	2	4	4	4
4	4	4	4	4	3	5	4	4	4	5	5	5	5	1	2	4	4	5	5
2	2	2	2	2	5	5	3	5	1	4	3	5	4	4	3	3	4	3	3
1	3	3	3	3	4	5	3	5	4	4	4	3	3	2	2	4	4	4	5
4	3		3		5	5	4	5	5	4	5	3	4	2	1	2	4	5	5
3	2	2	2	2	4	4	3	5	4	5	4	3	4	2	2	3	4	3	3
3	2	1	2	1	5	5	5	5	2	3	5	4	4	3	2	4	4	5	5
2	2	4	2	4	5	5	4	5	4	5	5	5	4	1	1	3	4	5	5
2	4	2	4	2	5	5	3	5	3	5	5	2	2	1	1	2	4	5	5
4	3	3	3	3	4	4	4	4	3	4	4	4	3	2	2	4	4	4	4
3	2	2	2	2	5	5	4	5	3	5	5	3	2	2	2	4	5	5	5
3	4	2	2	2	4	4	3	5	3	4	4	4	4	2	2	3	4	4	4
										4						1	4		
3	3	3	3	3	5	5	4	5	3	5	4	4	3	2	2	4	5	5	5
2	4	3	4	3	5	5	3	5	4	4	4	3	5	1	1	4	5	4	4
2	3	2	3	2	3	4	3	3	3	4	4	3	4	1	2	4	5	5	5
2	2	2	2	2	4	4	2	4	4	3	4	3	2	3	2	2	4	4	4
3	3	3	3	3	5	5	4	5	5	4	4	4	5	2	2	4	4	3	3

*Note that two items from Factor 3 required reverse coding.

APPENDIX F

Engineering Faculty Responses Attitude Survey Factor 6 through Survey Factor 12 (from Murray, Wren, and Keys, 2008)
(1=Strongly Agree; 5=Strongly Disagree)

Factor 6			Factor 7		Factor 8		Factor 9*			Factor 10		Factor 11*		Factor 12	
4	4	4	2	2	4	4	2	2	2	4	4	2	2	4	4
4	4	4		2	3	3	2	3	2	4	4	2	2	3	3
1	5	3	4	2	5	4	3	3	2	5	5	3	2	4	5
4	4	4	2	2	4	4	2	2	2	2	2	4	2	4	4
5	5	5	2	2	5	4	2	4	3	2	2	2	2	4	4
5	5	5			3	3									
4	4	3	3	3	4	4	3	3	3	4	4	3	3	3	3
4	4	4	2	2	4	4	2	2	2	2	2	2	2	4	4
5	5	5	4	4	4	3	3	2	3	4	4	3	3	4	4
4	4	4	2	2	4	4	2	2	3	4	4	2	2	4	4
5	5	4	2	3	5	5	3	3	3	4	5	4	3	4	5
4	5	4	5	3	4	4	3	3	3	4	4	3	3	3	5
4	4	4	3	3	4	4	4	3	2	2	3	2	2	4	5
5	5	5			4		2	1	1	1	1			5	5
2	5	5	4	4	5	5	2	4	2	2	2	5	5	2	5
5	5	5	2	1	5	4	3	5	5	1	1	2	1	3	5
4	5	5	1	1	5	5	1	1	1	5	5	1	1	5	5
5	5	5	3	3	5	5	1	1	1	1	1	3	3	4	5
4	4	4	2	2	4	4	2	2	2	2	2	2	2	2	4
5	5	5	2	2	4	4	2	2	1	2	3	3	2	5	5
5	5	5	3	3	4	4	2	2	2	2	2	3	4	3	4
4	4	4			4	4									
4	5	5	2	2	5	5	2	4	2	5	5	2	2	5	5
5	5	5	3	2	4	4	1	1	1	1	1	3	2	5	5
3	5	3	1	1	5	4	1	2	2	2	2	3	3	3	3
4	4	4	2	2	4	3	2	3	2	2	2	3	2	2	4
5	5	5	2	1	5	5	1	1	1	2	2	3	1	4	5

*Note that two items from Factors 9 and 11 required reverse coding.