Incorporating ASCE's ExCEEd Principles in Capstone Project and Other Active Learning Courses

Jennifer Q. Retherford[1] *[Joseph K. Amoah*[2]*]*

Abstract – Capstone Projects, or Senior Design Courses, are traditionally active learning environments and design of these courses requires consideration of teaching styles, learning styles, and the potential mismatches therein. The challenge of creating teaching and learning opportunities can be difficult for professors and frustrating to students. A deliberate effort is necessary to facilitate learning in an active environment largely unlike the traditional undergraduate experience. The American Society of Civil Engineers (ASCE) Excellence in Civil Engineering Education (ExCEEd) teaching workshop promotes teaching and instructional strategies evaluated by extensive research specific to the Civil Engineering discipline. These principles are well adapted to traditional lecture style courses, but the application in active learning settings requires special consideration. This paper evaluates the ASCE ExCEEd teaching model for use in Capstone Project courses, develops recommended best practices for effective teaching and learning in these courses, and presents a case study from the University of Tennessee at Knoxville.

Keywords: Capstone Project, Senior Design Course, ASCE ExCEEd

INTRODUCTION

Capstone Projects, or Senior Design Courses, are arguably the most valuable learning experience in the Civil Engineering undergraduate experience, yet they can also be the most frustrating learning experience. Capstone project courses offer students an opportunity to demonstrate skills developed throughout their undergraduate studies in an environment that is traditionally a hands-on, active learning atmosphere. In addition to Capstone Projects, many laboratory courses engage students in an active learning environment that can be difficult for some students. Active learning environments are essential to education in engineering as the principles and lessons addressed often represent physical behaviors. Additionally, these aspects of education often demonstrate the true activities that these students will be asked to perform as professionals.

Active learning environments cater to a specific learning style that is often dissimilar to the typical undergraduate course. For many students, the opportunity to guide themselves through a project independently is unique and readily embraced by students who excel in a self-reliant learning atmosphere. Conversely, many students feel removed from their customary learning atmospheres and may struggle adapting to the new conditions.

The teaching methods in primarily active learning courses must be deliberately organized in order to provide an environment that caters to all learning styles. Specifically, consideration of reflective, visual, intuitive, and sequential learning styles must be addressed through appropriately coordinated course activities. For example, the inclusion of passive learning experiences in an active environment often requires specific coordination to ensure that students with preferred reflective learning styles are satisfied.

The American Society of Civil Engineers (ASCE) Excellence in Civil Engineering Education (ExCEEd) Workshop introduces a teaching model with principles that are applicable to both traditional lecture courses and active learning courses. The ExCEEd model was designed to specifically address the potential mismatch between teaching and learning styles. To ensure that all students are engaged in the learning experience, the model recommends

[1] University of Tennessee, Knoxville, 315 John D. Tickle Building Knoxville, TN 37996, jretherf@utk.edu

[2] University of Tennessee, Knoxville, 323 John D. Tickle Building Knoxville, TN 37996, jamoah@utk.edu

diversifying the teaching method through all aspects of the course. This includes incorporating use of physical models during lecture, in-class activities, questioning during lecture, and appropriate design of assignments and examinations. Use of diverse learning opportunities provides students of all preferred learning styles an opportunity to engage with the professor during a lecture period. This can be challenging for active learning environments because the lecture period is often structured differently than a lecture style course.

Diverse teaching approaches are necessary in traditional courses and those techniques require slight modification in primarily active learning environments. The principles and lessons within the ExCEEd model can be applied to any course, but special consideration and effort is necessary to appropriately apply the model to active learning conditions. The remainder of this paper evaluates the ASCE ExCEEd teaching model for use in Capstone Project courses, develops recommended best practices for effective teaching and learning in these courses, and presents a case study from the University of Tennessee at Knoxville.

BACKGROUND: ASCE'S EXCEED TEACHING MODEL

The ASCE ExCEEd Workshop is an intensive experience that shares a teaching model developed by a number of faculty members from the United States Military Academy at West Point [ASCE, 1]. This model is founded on research performed specifically in the field of civil engineering education and emphasizes organization of a lecture, engagement of the audience, enthusiasm, student rapport, and assessment of student performance. A brief outline of the major ExCEEd teaching model principles is presented in Figure 1.

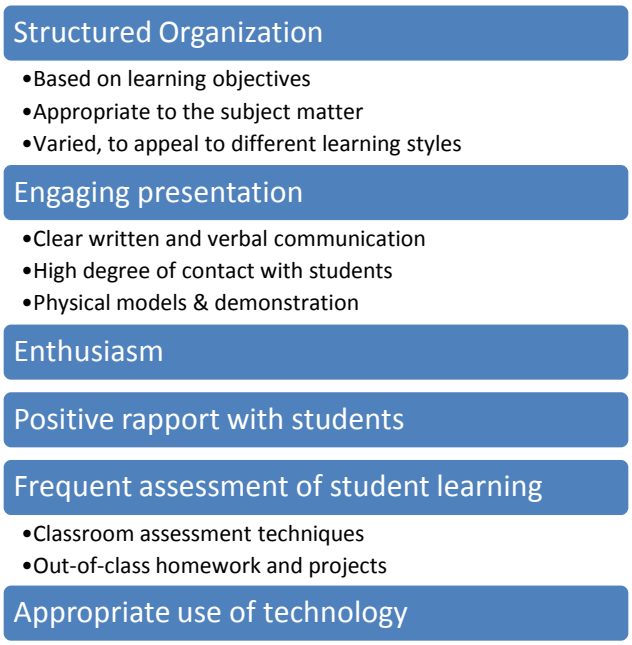

Figure 1. ASCE ExCEEd Teaching Model Principles

The teaching model developed by ExCEEd is considerate of both preferred teaching and learning styles. Research related to the faculty and students in civil engineering courses presents a strong likelihood of a mismatch between preferred teaching and learning styles. This mismatch is overcome through the ExCEEd teaching model through deliberate design of an education experience that includes opportunities for learners of different preferred styles.

The role of the educator in the ExCEEd teaching model is critical to the success of the engineering student. Lowman's two-dimensional model of teaching is one of the founding principles in the ExCEEd model. Lowman's model provides a ranking system for a professor with respect to both the interpersonal rapport with students as well

as the intellectual excitement that is generated by this professor [Lowman, 4]. Lowman recognizes that professors more easily improve their presence in the classroom by expressing excitement about the subject material than through development of relationships with students. Therefore, development of a course can begin with a focus on the course content and the delivery of this information to the students. Faculty members are encouraged through these findings to focus initially on development of an engaging and intellectually interesting course, and improve reputation, personal relationships, and rapport over time.

The impact of learning styles on education was a second major component in the development of the ExCEEd teaching model. Research by Felder and Silverman [Felder and Silverman, 3], a primary source for the development of the ExCEEd model, recognizes six components of learning. The ExCEEd model recommends engaging students across all dimensions and within each dimension to provide a diversified learning experience for students. This diversification not only improves retention of lessons for students when lessons are taught within their preferred learning styles, but also challenges students to react to teaching methods that are outside their preferred style.

The ASCE ExCEEd workshop overcomes challenges in education in engineering by combining principles of teaching and learning with a focus on developing an exciting learning atmosphere. Emphasis on the use of physical models and technology encourages professors to provide captivating learning experiences. Intellectual excitement and personal rapport are recommended as practices that encourage positive student development.

EXCEED PRINCIPLES FOR CAPSTONE COURSES

The principles for teaching described in the ASCE ExCEEd teaching model are easily and directly applicable to Capstone Courses. A number of principles of the ExCEEd teaching model are described herein and recommendations for implementation in capstone and active learning courses are presented.

Appropriate Instructional Strategy

The instructional strategy, or teaching model, for a traditional lecture course can be equally suitable in an active learning course such as a Senior Design Project course. The ASCE ExCEEd teaching model, described in Figure 1, is recommended for all civil engineering courses as a successful and well-researched model.

Use of the ExCEEd teaching model in an active learning environment only requires consistency of delivery and flexibility of instructional preferences by the professor. Rather than organization of a traditional lecture, the course organization is easily expressed with online course tools and communication. University systems such as Blackboard provide an excellent tool for sharing learning objectives and opportunities for learning for students. While lecture opportunities may be limited, each presentation by the professor must incorporate energy and enthusiasm to convey the intellectual excitement held by the professor for the course. Assessment of student learning can be performed intermittently within the semester, similar to traditional lecture-only style courses.

Effective Teaching Principles

Effective teaching principles do not vary between traditional and active learning courses, but modification at the individual faculty level may be necessary. The ASCE ExCEEd teaching workshop highlights Lowman's two-dimensional model of teaching as a resource for professors to gauge and improve their teaching effectiveness. The balance between intellectual excitement created by the professor and the interpersonal rapport developed between the professor and the students is considered paramount in developing a successful learning environment.

Intellectual excitement is often conveyed within lecture experiences, during which time a professor can demonstrate their mastery of the subject material in a public manner. The ExCEEd teaching model recommends that faculty coordinate a well-organized lecture, provide opportunities for critical thinking for the students, and engage the students with positive feedback and enthusiasm to ensure that students are aware of the professor's genuine interest in both the subject matter as well as student learning. This opportunity is often more difficult during capstone courses which do not necessarily have typical lecture opportunities. Most capstone courses have limited lecture time, which requires the professor to engage with students in a more deliberate and direct way. While a professor can address the entire student group in a single lecture, enthusiasm and positive feedback with the students in a capstone course may occur over multiple course meetings. Intellectual excitement in an active learning course may require small group meetings, written communication, and frequent personal feedback interactions to ensure that students are engaged with the professor on a regular basis throughout the semester.

Interpersonal rapport between the professor and student is also achieved during lecture hours, during which time the ExCEEd teaching model recommends a variety of techniques that engage students. Memorization of student names, greeting students as they enter the classroom, and engaging the students by name during questioning within the lecture improve the professor's relationship with students. These educational techniques can also be applied in active learning courses, but additional effort may be necessary when meeting times are flexible and students are not obligated to interact on a daily basis. A more deliberate and dedicated effort is required by a professor, which may be improved through scheduled interactions in small groups and through written communication.

Consideration of Learning Styles

Consideration of different learning styles is critical to the success of an active learning environment. During traditional lecture courses, the ExCEEd teaching model recommends variety in the lecture delivery to engage students in different ways. This variety exposes students to both their preferred learning style as well as those less preferred. Exposure to preferred learning styles improves student learning, but students also benefit from their less preferred learning style which is an opportunity for personal growth and independence in learning.

Traditional lecture courses can be modified to engage students according to a variety of learning styles. The ExCEEd model recommends preparing lectures that vary across the Felder learning styles to ensure that students of all preferred learning styles are engaged throughout the semester. Presentations that introduce theory can be manipulated throughout the semester to address deductive or inductive learners, sequential or global lessons, or intuitive or sensory concepts. Lectures can be designed and executed to an audience of active or reflective learners through traditional oral lectures which provide an opportunity to absorb a lesson before application or learning activities that require immediate implementation of concepts. Visual or verbal learners are engaged through tools such as videos, PowerPoint, board notes, or reading assignments.

Teaching according to a variety of learning styles in a capstone or active learning course requires deliberate course organization. Again, the lack of a formal lecture requires scheduling opportunities for student learning in non-traditional ways. The typical mismatches between teaching and learning styles in active learning courses requires a unique need for deliberate course design that incorporates all learning styles. Small group activities may be necessary to engage students in coordinated learning opportunities that incorporate lessons taught with consideration of specific learning styles.

The typical coursework in a capstone course may vary depending on the overall design project. For example, a project may begin with abstract ideas that may engage intuitive learners, or clear analytical circumstances that engage sensory student learners. This variety may require unique design in each semester the course is provided.

Clearly Defined Learning Objectives

Learning objectives are critical to clear and direct guidance for the expectations of a task in a capstone course. The ASCE ExCEEd teaching model recommends the use of well-defined learning objectives during every lecture opportunity and focuses on the use of Bloom's taxonomy as a resource for appropriate active verbs. Learning objectives are viewed as a direct description of the required learning from the professor to the student and is a tool later utilized for assessment of student learning. The ExCEEd teaching model recommends that the professor clearly define the learning objectives for each lecture and communicate the objectives at the start of each lecture. The model recommends that homework and exams for the course be designed directly with the learning objectives in such a way that the expected learning objectives correlate exactly with the learning objectives shared during lecture.

Use of learning objectives in active learning courses is very valuable in communicating expectations between the professor and the student. Rather than sharing learning objectives during lecture opportunities, however, capstone course professors must convey learning objectives through alternate means. One recommendation is through written assignments and example grading rubrics. Consistency in the written course assignments and student assessments is recommended to ensure that students are made aware of the lessons intended by the professor in a learning environment where a professor may not be able to directly speak to each student in a frequent manner.

Communication and Personal Rapport

Communication in an active learning course may require different techniques and technology, but follows the same principles as a traditional lecture course. The ASCE ExCEEd teaching model emphasizes the importance of written and oral communication throughout a semester to engage students in questioning, as a means to ensure student

understanding, and to promote a positive rapport between the students and the professors. Effective questioning, reading non-verbal cues from students, and engaging students in critical thinking activities are all recommended practices during lectures according to the ExCEEd model.

The use of verbal and non-verbal communication, in accordance with the ExCEEd principles, can be achieved with equal success in active learning courses. Questioning during capstone courses may require one-to-one meetings or small group activities to engage students in a conversation about the lesson. Non-verbal communication may require more direct interaction with students and may be more difficult to read as it may occur outside of scheduled course times. A necessary balance must occur for which the professor has an opportunity to "read" the students' reaction to lessons and required tasks without being overbearing or micro-managing student progress through the semester. Use of student leaders may improve these communication opportunities, but the responsibility lies solely with the professor.

Personal rapport with students during a capstone or active learning course requires effective organization of the course and demonstration as a manager of student learning. Enthusiasm and engagement in the course project improves the rapport between the professor and student as all parties share the common goal of completing a successful project. Personal rapport within capstone projects requires hands-on involvement with all student participants.

IMPLEMENTATION & RECOMMENDED BEST PRACTICES

Implementation of the primary ExCEEd principles in a Capstone Course requires special consideration as opposed to traditional lecture-style courses. While the ExCEEd teaching model is appropriate for all civil and environmental engineering courses, professors must make intentional efforts at engaging students in the learning process. The ExCEEd teaching principles described in the previous section were implemented in the Senior Design course at the University of Tennessee, Knoxville, during the Fall 2013 semester. A brief description of the practices implemented and observations is provided herein.

An appropriate instructional strategy and effective teaching principles are clearly applicable to all courses, but the conveyance and execution in an active learning course requires deliberate design. Course organization in many traditional courses is centered on a well-designed lecture, coordinated at-home assignments, evaluation, and final assessment techniques. In a course without regularly scheduled lectures, the organization of the professor must be clarified through alternate means. The use of online management tools, such as Blackboard and other university-based communication methods, provides students a resource to recognize the order of the course. A well-written syllabus that is repeatedly referred to through oral and written communication is an excellent tool to demonstrate the objectives and deliverables necessary throughout the semester. When the course has flexible scheduling, this syllabus can become a valuable reference document for students if they are properly made aware and reminded of the information contained in the syllabus. The Fall 2013 Senior Design course was provided with a syllabus and schedule on the first day of the semester, and this document was directly referenced in all later graded assignment documentation to ensure that students understood the organization of the course and the means for evaluation.

Consideration of learning styles may appear to be a particularly challenging component to effective teaching in an active learning course, but diverse learning styles can easily be accommodated with intentional design. As opposed to traditional lecture courses, active learning courses require independent work by students. This has the opportunity to reduce the potential mis-match between teaching and learning styles as students can engage in their preferred method of learning on an individual basis. Professors of active learning courses must make special effort to clarify learning expectations and to encourage independent study, but the responsibility of addressing variable learning styles becomes the responsibility of the student rather than the professor. While informally addressed during the Fall 2013 semester, consideration of learning styles was implemented through direct interactions with students to provide leadership and guidance in evaluating their learning needs and recognizing sources of information.

Learning objectives are a proven component to effective teaching and are highly recommended in many teaching models. While lectures are often the preferred venue for sharing learning objectives, as recommended by the ExCEEd teaching model, Senior Design courses may not have regularly scheduled lecture sessions. Learning objectives may be best conveyed within graded assignment documents to clarify expectations for students. Well written learning objectives, utilizing active verbs as recommended by Bloom [Bloom et al., 2], provide a tool for developing grading rubrics and describing to students the metrics that will be later utilized for assessment of

performance. Each graded assignment provided to the Senior Design course students included a clear description of the learning objectives and an associated grading rubric to clearly define the learning objectives expected by the professor.

Finally, communication and personal rapport is a critical component of active learning courses. Traditional lecture-only courses rely on oral communication and personal rapport which are primarily achieved within regularly scheduled course times. Capstone and other active learning courses require more communication through written means. Again, many university systems provide online tools that enhance the professor's ability to communicate easily in written form. One-on-one interactions are extremely valuable in active learning courses, possibly providing a greater opportunity to improve personal rapport. However, this requires deliberate and intentional interactions between the professor and the student. Small group meetings and consultations are recommended as methods to engage students in opportunities to communicate with the professor. During the Fall 2013 Senior Design course, written communication was a priority. Oral communication was achieved at the discretion of the advisor, with strong consideration of the personal rapport needs for each student. While some students prefer frequent communication, many preferred only periodic interactions with the professor. To supplement the limited oral communication, guest professors and engineers were invited to the class to engage students who were not highly communicative during regular course hours. Students were very responsive to opportunities to communicate with more individuals than the single course professor.

CASE STUDY

Three primarily active learning courses were surveyed to evaluate the implementation of select ExCEEd principles. This is a preliminary survey and additional research will be necessary to fully substantiate the benefits of utilizing ExCEEd teaching principles in active learning courses.

Courses Evaluated

The students from three core civil engineering courses were surveyed to evaluate the impact of ExCEEd teaching principles on student engagement and student learning. The Geomatics Laboratory, Water Resources Engineering Laboratory, and Senior Design Course are three active learning courses that rely on laboratory and hands-on experiences as the primary mode for student learning. These courses were selected for this survey because of their unique similarities and differences. These courses are all highly active learning courses that require students to participate in laboratory exercises or produce coursework in a highly independent setting. Professors provide less direct instruction and rarely engage in traditional lectures as the mode for teaching. Rather, teaching is achieved through experience by the students and supplemented by interactions with the professors. While some similarities exist, the courses vary dramatically in the level of students participating in the courses and the coursework performed by the students. The Geomatics Laboratory is traditionally a sophomore level course, while the Water Resources Engineering Laboratory and Senior Design courses are comprised almost entirely by senior level students. Further, the Geomatics Laboratory is guided very directly by graduate student teaching assistants (GTAs), whereas the Water Resources Engineering Laboratory requires more independent student work. The Senior Design course is the most independent learning environment, during which students are provided a minimal amount of direct instruction and are required to seek out assistance more deliberately outside of typical course hours.

Impact of ExCEEd Principles

The students in the courses examined in this case study directly benefited from principles in accordance with the ExCEEd teaching model. Five primary ExCEEd principles were specifically investigated: appropriate instructional strategy, effective teaching principles, consideration of learning styles, clearly defined learning objectives, communication, and personal rapport.

An appropriate instructional strategy and effective teaching principles are recommended by the ExCEEd model as a necessary component of effective teaching. Consideration for organization of a course, providing students relevant information, stimulating critical thinking, and providing appropriate evaluation and assessment are all components of an effective teaching model for any style of course. The students in these active learning courses indicated a minor value in an appropriate instructional strategy with respect to teaching effectiveness and stimulation of interest in the subject matter. The students surveyed clearly cited the instructor's teaching method as impactful in their learning and thought process for an active learning course, as illustrated in Figure 2. Figure 3 demonstrates the student perception of the professor's teaching method on students' interest in the subject matter. While a majority of

students may not find the teaching model to have a major effect on student learning, they are clearly perceptive of the impact of the instructor's instructional strategy on their learning.

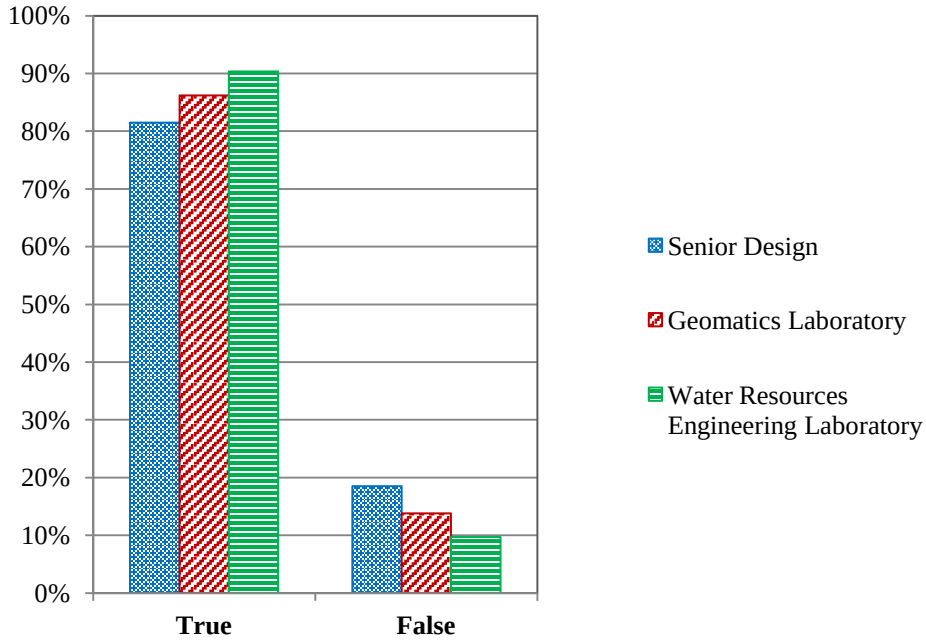

Figure 2. Impact of Teaching Method on Learning in a Course

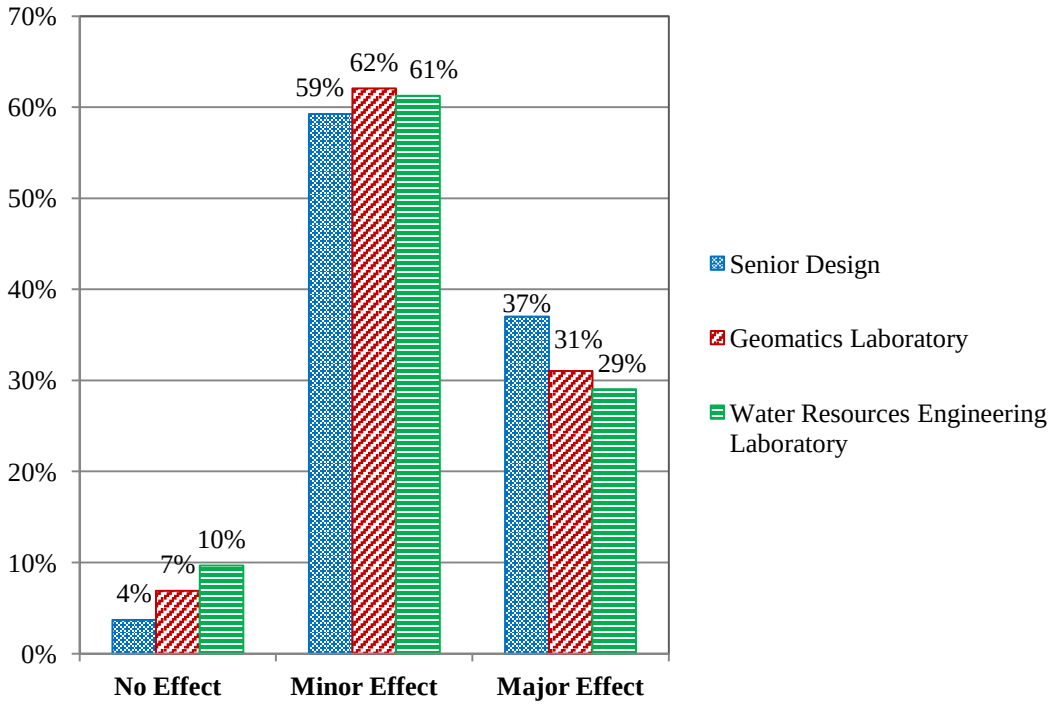

Figure 3. Impact of Instructor's Teaching Method on Student Interest

Use of learning objectives in traditional lecture courses provide a great opportunity to orient students to a particular lesson or lecture topic, but conveyance of learning objectives can be challenging in non-lecture courses. Learning objectives in the Senior Design course this semester were shared in the written documentation for assigned work throughout the semester. Learning objectives for the Geomatics and Water Resources Engineering Laboratories courses were also presented to students through written communication methods. While some variation between courses occurred, many students find learning objectives to be a valuable tool in recognizing the expectations of professors. A very strong majority of students in the Senior Design course indicated a high importance associated with formal communication of learning objectives. This emphasizes the importance of sharing clear expectations of learning in courses that require significant independent student work.

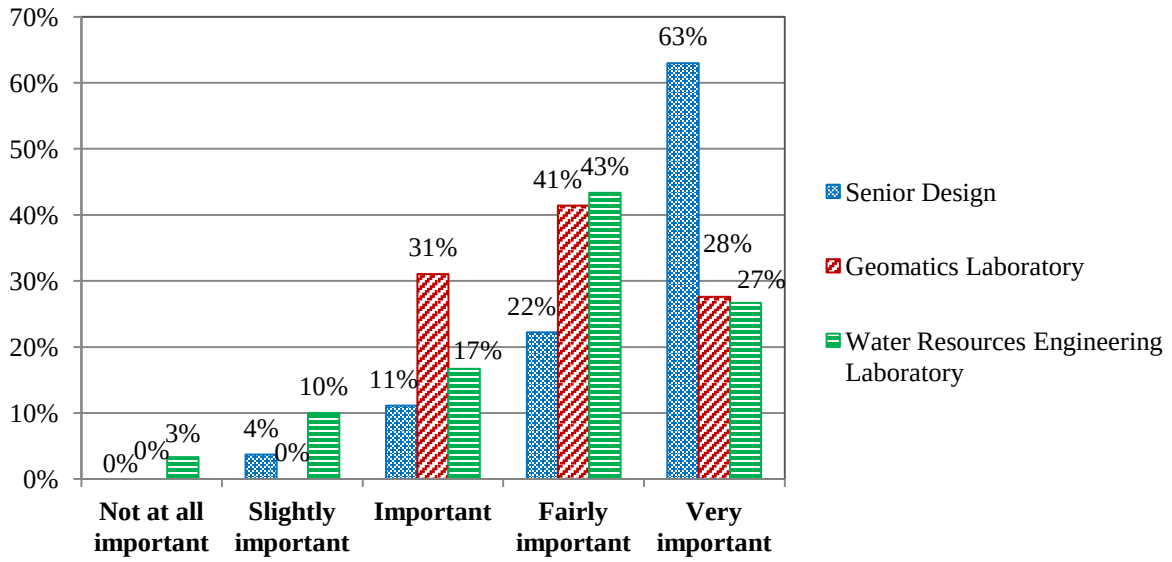

Figure 4. Importance of Formal Communication of Learning Objectives

Another component of the ExCEEd teaching model investigated in this case study is the consideration of various learning styles in the teaching method. Interestingly, many of the students surveyed indicated that while they may have a preferred learning style, they were not restricted to a single learning process. More than 90% of all students surveyed indicated that they were capable of adjusting to the teaching methods of instructors in active learning courses. This may be an indication of the independence of student learning in such courses and the ability of students to recognize the responsibility of learning more clearly in hands-on courses.

Communication and personal rapport is a component of effective teaching promoted by the ExCEEd principles that are also shown to be valuable to the students surveyed in this case study. Students were surveyed to understand the impact of various forms of communication on student interest in a course. Personal interaction was shown to be very important to students, clearly indicating the importance of communication as well as personal rapport on student learning in a course. Interestingly, the impact of office hours was quite diverse. This may be due, in part, to the flexibility in work load throughout the semester in non-lecture courses. Regularly scheduled office hours are clearly not as effective as prompt feedback, which is expected in a course where the individual's schedule may not coincide with an overall class schedule. Courses such as the Senior Design course provide individuals an opportunity to define their personal schedules much more diversely than traditional engineering courses that have scheduled assignments and exams. In an open-ended question for students participating in active learning courses, students were asked how personal rapport enhanced their learning experience. An overwhelming number of responses indicated that personal rapport was an absolute necessity in providing a learning environment that allowed for opportunities to ask questions, opportunities to "be wrong", and motivate them to interact. One respondent indicated that interaction as straight-forward as completing assignments and attendance in lecture was significantly impacted by their relationship with the professor. The student indicated that the personal rapport increased the "sense of responsibility" that the student had in their participation in the course.

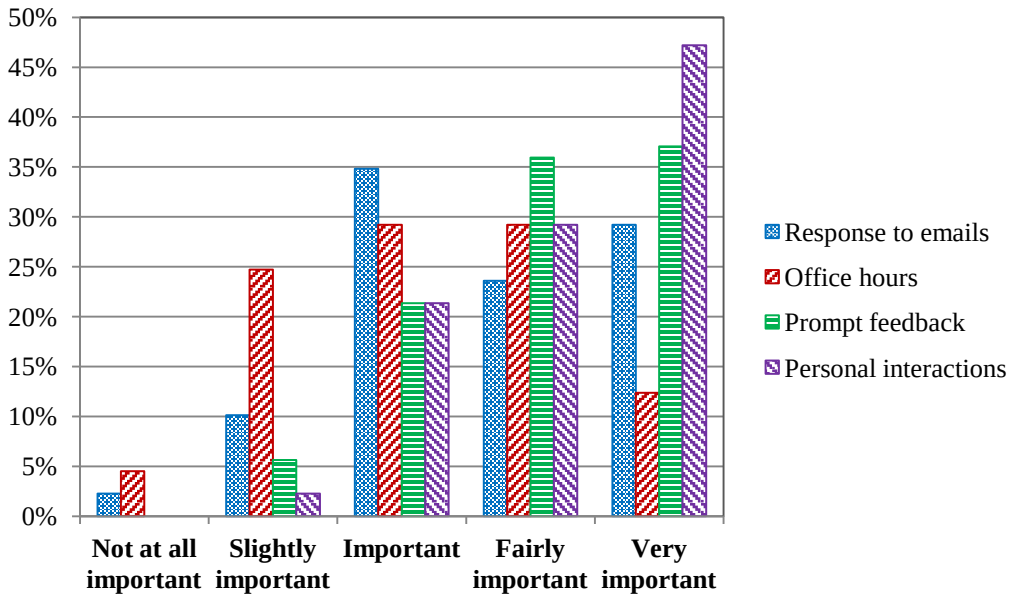

Figure 5. Importance of Effective Use of Formal Communication to Promote Student Excitement for Course

CONCLUDING REMARKS

The ASCE ExCEEd teaching method, a model developed for and implemented in traditional civil engineering lecture courses, has been evaluated for adoption and extension to Capstone Project courses and other active learning environments. Although, active learning environments require special consideration of teaching and learning styles dissimilar from traditional lecture-style courses, this paper has demonstrated that the core ExCEEd framework principles are applicable to active learning courses by carefully following recommended best practices. The recommendations evolved from implementation of select ExCEEd principles including appropriate instructional strategy, effective teaching, consideration of learning styles, clearly defined learning objectives, and communication and personal rapport in a Senior Design Course. A survey conducted for three core civil engineering active learning courses to evaluate impact of ExCEEd principles indicate that tactful implementation of ASCE ExCEEd teaching model is valuable in engaging students in a course that is often dissimilar from other undergraduate civil engineering courses.

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Jennifer Q. Retherford

Dr. Jennifer Retherford is a Lecturer in the Civil and Environmental Engineering Department at the University of Tennessee, Knoxville. Dr. Retherford's research interests include: structural engineering, pavement engineering, risk and reliability analysis, and pedagogy in engineering. She completed her undergraduate education at the University of Nebraska in Omaha, and master's and doctoral studies at Vanderbilt University. Dr. Retherford is a licensed civil engineer in the state of Tennessee.

Joseph K. Amoah

Dr. Joseph Amoah is a Lecturer in the Civil and Environmental Engineering Department at the University of Tennessee, Knoxville. Dr. Amoah's research interests include: sustainable water supply, green and resilient water infrastructure systems, urban water management, flood control, and low impact developments. He completed his undergraduate education at Kwame Nkrumah University of Science and Technology in Kumasi, Ghana, and master's and doctoral studies at Florida A&M University. Dr. Amoah is a licensed civil engineer in the state of Florida.