AC 2012-3084: INTEGRATING THE CHARRETTE PROCESS INTO ENGINEERING EDUCATION: A CASE STUDY ON A CIVIL ENGINEERING DESIGN CAPSTONE COURSE

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Integrating The Charrette Process into Engineering Education: A Case Study on a Civil Engineering Capstone Course

ABSTRACT

As engineering educators rethink the structure and value of capstone courses, many have turned to practical applications. In order to reflect the recent approaches within engineering, capstone courses can be enhanced through the integration of charrettes. Charrettes are hands-on, collaborative sessions where stakeholders come to a design consensus. These sessions provide opportunities for students to improve communication, technical evaluation, teamwork, peer evaluation and professionalism skills. This research provides a framework for adapting the charrette process to an academic setting as well as evaluates the strengths and challenges associated with academic implementation. Implications such as time constraints, resources, and setting are explored and adapted for the needs of an academic design course. A case study application on a senior level civil engineering design course revealed that the design charrette framework can be successfully implemented within an academic setting. Through the charrette process, designs were integrated into one Master plan that incorporates the strengths of each team. Challenges faced throughout the process are provided as recommendations for future application.

INTRODUCTION

As engineering educators look to provide more opportunities for practical applications of the comprehensive design process, capstone courses have become mainstream.[1] Capstone courses are typically upper level classes focused on open-ended, real world design problems that require students to apply multidisciplinary approaches to problem-solving.[2] Capstone courses can be enhanced through the integration of design charrettes, which are stakeholder-driven collaborative sessions that lead to a design consensus. Design charrettes have evolved in response to the challenges facing traditional engineering research design methods. [3]

Traditional engineering research design methods include using structured public hearings and client meetings to gather community input and stakeholder perspectives. Using these traditional approaches in isolation can lead to barriers and challenges that hinder access to information including low response rates, travel costs, lack of access to project data, miscommunication, and time commitment.[3] Rather than continuing to utilize these research methods in isolation for practical design, an adoption of a step-by-step innovative planning process is being used.

In contrast to the traditional model, a more holistic step-by-step process that provides a multi-perspective approach toward planning is proving to be more effective and efficient. [3] This process, known as a design charrette, is a brief but intense, hands-on collaborative session in which stakeholders from different backgrounds work together to come to a design consensus.[4] Engineering design can be defined as the “process of devising a system, component, or process to meet desired needs” which results in the “best” design for the client.[5] Therefore, design activities can greatly benefit from group collaborations that allow for a comprehensive evaluation of alternative solutions to problems.[6]

In parallel to the practice of engineering, academia can benefit from the integration of a more team-based learning approach for design. In contrast to the traditional lecture, design-based capstone courses can provide a unique experience of team building, practical application, multidisciplinary exposure, a more comprehensive evaluation of the problem, and serve as a "gateway into the real world".[7] By approaching problems from a multidisciplinary perspective, a more comprehensive evaluation of the issues related to the design process can be used, including generation of additional alternatives and consideration of unintended consequences.[6]

By implementing a design charrette in the academic setting, students can be exposed to the real world charrette process. Allowing the students to research stakeholder perspectives provides a more holistic design experience where they can together, as a large team, come to a design consensus. Unlike traditional design, the students are provided a venue to voice all design considerations before selecting a final design. Implementing the charrette process encourages a thorough feasibility assessment of all alternatives and provides the opportunity for creativity in design rather than rushing the planning process. Within the process they have to effectively communicate and evaluate the strengths and weaknesses of each design alternative. Therefore, utilizing a charrette process can allow students to gain the necessary skills required to be successful in engineering practice including communication, technical evaluation, teamwork, peer evaluation and professionalism.

As the concept of the charrette process has become better defined through efforts by the National Charrette Institute[8], these principles can be applied to upper level engineering design courses. The National Charrette Institute (NCI) has developed three main steps within the process: (1) research, education, and charrette preparation, (2) charrette, and (3) implementation.[8] Although the charrette framework is developed for a real world design, the framework can be adapted and modified for the purposes of the academic environment and timeframe.

An adapted framework for design charrettes for use in academia is provided as an effective approach to capstone design. In order to evaluate the application of the adapted design charrette framework, a case study on a senior level Civil and Environmental Engineering design course, cross-listed with an Engineering Studies course at Lafayette College, is used. The Engineering Studies course provided students from various disciplines. The main purpose of the shared course was to develop a revised Master Plan that incorporates sustainability for an off-campus athletic site. Therefore, the final deliverables were civil engineering design plans as well as a professional presentation to stakeholders. Since there were approximately forty students in the course, many from different backgrounds, a formalized, methodological process was needed to engage each student in the process. Therefore, the charrette process was chosen as a way to narrow the group design ideas into one final plan.

The primary objective of this paper is to evaluate the benefits and challenges associated with integrating design charrettes into the academic setting, specifically engineering design courses. Background concepts about the charrette process are defined along with the modifications needed to integrate the process into academia. A case study application to a senior level civil engineering design course is discussed in terms of the goals, logistics, student perspectives, and lessons learned from integrating a design charrette into a capstone course. Recommendations are then provided for future applications of a charrette process into a similar engineering course.

BACKGROUND: CHARRETTE CONCEPTS

This section provides background information on the design charrette process and the associated guiding principles. The charrette framework and strategies are discussed along with the overarching benefits of utilizing the charrette process in planning and engineering design.

What is a Design Charrette?

The design charrette process developed in response to the need for a more holistic approach to gathering information and collecting varying perspectives on a common goal. Rather than continuing to use surveys, interviews, and traditional focus groups in isolation for collecting information, the charrette process is based on the strengths of all three.[3]

A design charrette is an intense collaborative session where stakeholders and interested community members work together to discuss a design issue.[9] In contrast to traditional engineering design which tends to be linear, the goal of a design charrette is to use a highly facilitated, iterative, multi-disciplinary approach to break down problems, generate alternatives, consider unintended consequences, and prepare participants to make informed decisions about how to apply the results.[6] Rather than streamlining the design process, the charrette process allows for the opportunity to share ideas and evaluate the design in iterations to achieve the most effective design. At the conclusion of a successful charrette, the participants have identified performance objectives and needs in the context of the plan or program.[9] The charrette process has been specifically developed for the following disciplines[8]:

- Sustainable community and building design
- Master planning
- Regional and comprehensive planning
- Transportation/infrastructure planning
- Development projects
- Code/policy writing

In particular, the area of sustainability has greatly benefited from this process. Since sustainable building design and neighborhood planning requires a comprehensive, holistic approach, the use of a multidisciplinary strategy is necessary.[9] Therefore, integrating the perspectives of different stakeholders (site developers, construction workers, operations and maintenance crews, planners, building designers and community members) into one plan provides opportunities to reduce environmental, social, and economic impacts. However, regardless of the discipline, this process provides a rigorous step-by-step method for gathering perspectives and coming to a general consensus.

Charrette Framework

The charrette process is well-defined by the National Charrette Institute[8] which is a nonprofit educational institution that helps to integrate community interaction into planning. Each step of the National Charrette System has been developed specifically for use by designers, architects, developers, and community activists.[8] Therefore, the training, the formal workshop, and the timeframe are suited for the duration of a typical community project. Based on NCI[8] there are three phases that make up the charrette framework:

- Phase 1- Research, Education, and Charrette Preparation
- Phase 2- Charrette
- Phase 3- Plan Implementation

NCI[8] suggests one to nine months for the Research, Education, and Charrette Preparation (Phase 1), at minimum four days for the Charrette (Phase 2), and two to four months for the completion of Plan Implementation (Phase 3). Therefore, the entire charrette framework should take no more than thirteen months to complete.

In addition to following the systematic charrette framework, there are several key strategies that NCI[8] recommends to ensure that the planning process is successful. The strategies include the following[8]:

- Work collaboratively
- Design cross-functionally
- Compress work sessions
- Communicate in short feedback loops
- Study the details and the whole
- Produce a feasible plan
- Use design to achieve a shared vision and create holistic solutions
- Include a multiple day charrette
- Hold the charrette on or near the site

Assuming these strategies are met, NCI[8] suggests that numerous benefits are possible with the application of the charrette framework. By using short feedback loops and compressing the work sessions, time and money will be saved. By working collaboratively, focusing on cross-functionality and achieving a shared vision, the probability of design implementation can be increased. Using a broad stakeholder involvement that is built on long-term community goodwill can promote trust between citizens and government.[8] Lastly, sharing principles, and integrating all viewpoints can result in the "best" sustainable design.[8] Therefore, utilizing this process not only in practice, but in an academic design course, specifically related to sustainability, is beneficial.

METHODOLOGY FOR ACADEMIC INTEGRATION

Although the methodology for applying the charrette process into practice is well-defined, integration into the academic setting is relatively novel. The success of the charrette framework in the field[3] suggests the potential for an effective collaborative process to be integrated into a student learning environment. Therefore, a systematic charrette framework, specific to the academic setting is necessary. The following section describes the NCI charrette framework and adjusts the process to the academic environment, specifically for a senior level engineering capstone design course.

Adapted Framework for Capstone Course

With the support of the Accreditation Board for Engineering and Technology, Inc.[10], design capstone courses in the civil engineering undergraduate curriculum have become widely used since the mid-1990's.[11] Capstone courses provide the opportunity for students to develop a number of skills including application of engineering design principles, teamwork, and communication. These skills directly align with the principles and benefits of implementing design charrettes. Since capstone courses typically involve a comprehensive, semester-long design project conducted in teams, a design charrette can be adapted to the academic setting to enhance the collaborative process. Four adaptation areas are required for the integration of a design charrette into an academic setting: timeframe, participants, setting and environment, and instructor's role.

1) Timeframe: In order to adapt the framework for the academic setting, one of the first aspects that needs to be adjusted is the timeframe. NCI[8] recommends no more than 13 months to complete the entire process (Phases 1-3). Since a typical academic semester is about four months, the time periods have to be adjusted. Therefore, the academic charrette framework is one month for Phase 1 (Research and Preparation), one day for Phase 2 (Charrette), and about two to three months for Phase 3 (Plan Implementation). Although NCI [8] recommends a four-day process allotted for the charrette phase, a shorter more intense period such as a "charrette night" is recommended for the academic setting. The charrette night can be facilitated with the intention of covering the same goals as a four-day process but with a condensed timeframe. Figure 1 displays a comparison between the NCI timeframe and the adjusted timeframe for an academic course.

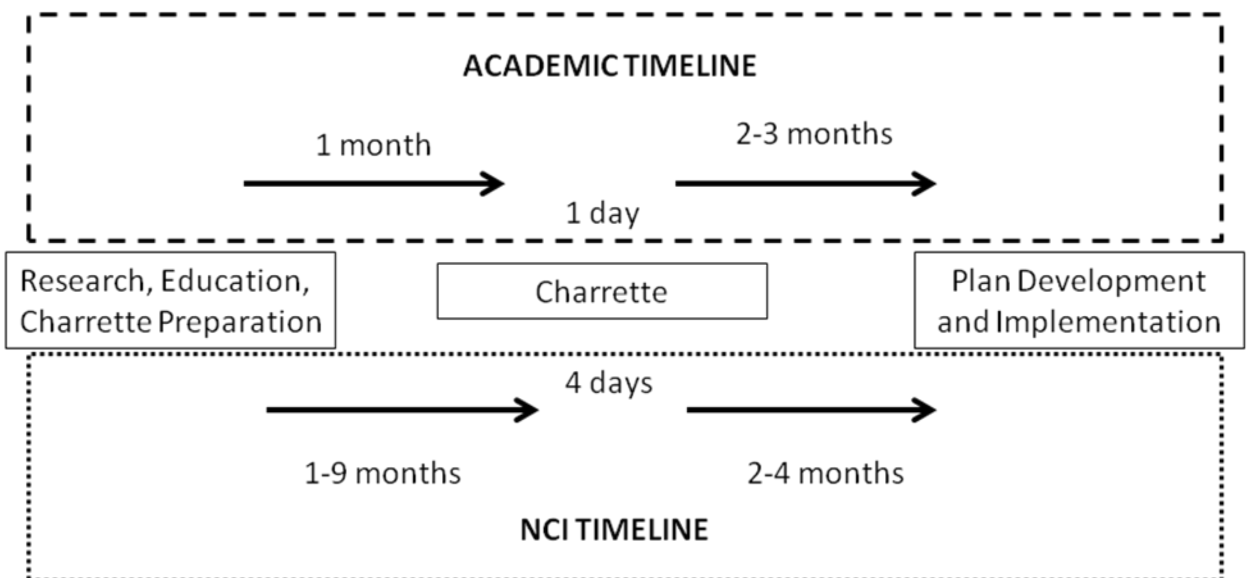

Figure 1- Comparison between Academic and NCI Timeline

As shown, the minimum length recommended by NCI[8] for Phases 1 and 3 are used as the recommended durations for the academic setting. This allows for the students to experience the iterative nature of the charrette process while still following the academic timeline. It is important to note that Phase 3 (Plan Implementation), for the purpose of academia, refers to the development of final plans or prototypes to be developed in the real world, within the appropriate time constraints of the course. By allowing the students a minimum of 2 months for this phase, they have the ability to produce a final product based on their collaborative design. In general, the overall academic timeframe is limiting and if possible, an extended duration for each of the three phases is recommended.

2) Participants: In terms of charrette attendees, typically the community and project stakeholders participate and provide their design perspectives. Sometimes it is not possible to identify and involve all possible stakeholders, however, the more perspectives represented at the charrette, the better, because it allows for a more comprehensive plan.

In an academic setting, the students can represent the differing perspectives individually or by dividing into groups and agreeing on a common vision or goal. Depending on the number of students enrolled in the course, the opportunity to use Team-Based-Learning (TBL) is advantageous.[12] TBL is recommended for class sizes of 10 to 400+ and is based on dividing the students into heterogenic teams that are strategically determined based on student strengths and weaknesses.[12] By doing so, TBL fosters interpersonal skills, student engagement and responsibility through permanent and purposeful heterogeneous work groups.[12] Since a charrette involves collaboration, dividing students into heterogeneous work groups to represent a specific perspective allows students to take ownership and responsibility for their work and participation. No longer are students directly reporting to the instructor, but now they are accountable to their peers as well.[13] Also, dividing the students into groups provides the opportunity for more teacher-student interaction.[13] Groups that combine a variety of student levels and backgrounds are ideal so that students are exposed to differing opinions within their own teams. Therefore, if there are at least ten students enrolled in the course, a TBL approach to a charrette process is recommended.[13]

3) Setting and Environment: NCI[8] recommends that the charrette be located near the actual design site, and when possible, this should hold true for in-class charrettes as well. Having the students visualize the plan by seeing the existing site in-person can enhance their understanding of the project as well as improve engagement.

Since the primary method of traditional engineering instruction focuses on lecturing[14], many educational facilities are designed around this technique. Rather than use a setting where there is a "lecturer" and an "audience", the classroom should be rearranged in a circular manner. Situating the students in a circle allows for equality when it comes to sharing their ideas and encourages everyone to be engaged.

4) Instructor's Role: In terms of the instructor's role, the students should be provided guidance throughout each of the three phases of the charrette process. For Phase 1 (Research and Preparation), information on the project background, timeline, resources, and objectives should be provided. During Phase 2 (Charrette), the instructor simply acts as a moderator for the discussion during the charrette process. For Phase 3 (Plan Implementation), the instructor can provide technical assistance as necessary. In general though, the capstone experience should allow students to complete a design process from start to finish in an attempt to simulate a real world project.[1]

Academic Benefits

Applying a charrette process using a team-based approach to a capstone course can offer significant potential for enhanced student learning.[1] Not only are students able to gain the benefits of completing the general engineering design process as specified in the ABET learning outcomes[15],but also they can be exposed to the experience of a practical, collaborative session.

As the charrette process continues to be increasingly utilized in engineering practice[3], students who participate in the process will graduate with the experience of having participated in a charrette. They can then bring their knowledge of the principles and benefits of conducting a multidisciplinary interactive session into the workforce. Therefore, the advantages of applying the charrette include both short-term (within the duration of the class) and long-term benefits (at the completion of the class). These benefits are shown in Table 1.

Table 1- Benefits of Applying the Charrette Process to Engineering Education

Short-Term Benefits	Long-Term Benefits
Completion of holistic design process	Experience with completing charrette process
Opportunity for multidisciplinary approach	Enhanced communication skills
Opportunity for informal peer evaluation	Ability to work with multidisciplinary perspectives
Improves student engagement	Experience of working in teams
Improves student ownership and responsibility	Knowledge of the benefits and opportunities of charrette applications
Increased student-teacher interaction	
Opportunity for students to develop design criteria	
Understanding of charrette process	
Improves sustainability of the design	
Applicable to all engineering fields	
Addresses ABET objectives	

The short-term benefits of implementing a charrette process in engineering classes include its applicability to a variety of engineering disciplines, the potential for enhanced overall sustainability of the plan, and the ability to address ABET[10] learning outcomes. In the mid-1990's engineering educators identified engineering design as one of the major areas needing improvement.[2] This continued need is addressed through ABET guidelines that encourage the use of approaches that build teamwork skills, communication skills, and multidisciplinary interaction, in addition to general engineering skills such as cost estimating, proposal writing, bidding, and developing professional deliverables.[1] Each of these objectives is a direct benefit of implementing the charrette process, specifically using TBL.

Many of the short-term benefits draw from the opportunity for TBL, in which students can become more involved, take ownership of their design, have increased student-teacher interaction, and hold responsibility of the success of the team.[13] Within the teams, students can build trust, support, cooperation and mutual respect for their colleagues, which creates an environment that improves participation, reduces student anxiety and reflects real world best practices.[16]

In addition, since the students are given the opportunity to share ideas and compare designs, informal peer evaluations can occur at two scales: team and class-wide. During Phase 1 (Research and Preparation), individual members within each team will offer suggestions and collectively, as a team, the ideas will be included in or eliminated from that team's vision. During Phase 2 (Charrette), the opportunity for a class-wide peer evaluation is provided. During this phase, where all teams come together as a class, the teams can evaluate each others' design. By having both the team and class peer evaluations, it allows the students to improve their own communication and performance skills.[17]

In addition, the two scales of peer evaluations simulate the process of a practical design review process used in the field. A typical engineering design is first critiqued in-house. Then, the plan is brought to stakeholders and members of the public for evaluation prior to development. This practical engineering design process is replicated through various opportunities for peer evaluation within the charrette process. For example, the charrette night serves as the "design review" process that the plan typically undergoes in engineering practice. This step of evaluation is critical to the engineering process and having students share this experience with their peers in a way that enhances student learning is truly invaluable. Ideally, by going through this process, they will be able to effectively critique as well as receive suggestions in a way that is beneficial to the entire team and overall goal of coming to a successful design plan.

The charrette process also provides students the opportunity to adopt and implement a more holistic, sustainable approach to engineering design. Rather than being assigned to one specific detail of the plan, students are involved in the entire process from start to finish. Throughout the process, they are exposed to differing backgrounds and perspectives which can encourage them to be creative and explore alternatives which may not be initially recognized. Also, by having the students strategically placed in teams based on their characteristics, the strengths and weaknesses of individuals are counterbalanced by their teammates.

Lastly, as a result of open-ended design problems, students are provided the opportunity to define the boundaries and explore the design criteria needed to complete the project. Since the instructor's role is primarily to provide guidance and assist with resources, the student has the opportunity to determine the level of detail as well as the information necessary to complete the project. In contrast to the traditional format where the student is giving the guidelines and boundaries within a well-defined problem, the student can now seek out those boundaries and explore areas outside the context of the course. For example, the real world design process includes exploring zoning codes, regulations, permits, etc. Students now have the ability to define how in depth they want to explore these areas to help them come to a successful and feasible solution to a real world problem.

These short-term benefits achieved during the class directly correlate to the long term achievements that can be used post-graduation. Whether students aim to go directly into the industry or to continue their education, the charrette process can enhance their communication, teamwork, problem-solving and multidisciplinary interaction skills.

Challenges

Implementation of the charrette process in academia leads to challenges from both the instructor and the student perspective. Table 2 displays a summary of the challenges as an instructor as well as a student.

Table 2- Challenges of Applying the Charrette Process to Engineering Education

Instructor Challenges	Student Challenges
Evaluating individual student contributions to team product	Evaluating peers based on their individual performance
Defining the project scope and design criteria	Using creativity to explore design options beyond the project information provided
Condensing the timeframe for academia while maintaining the components of the charrette process	Completion of timesheet to determine individual tasks
Maintaining an appropriate team size that addresses the goal of a "small group" for the charrette night	Determining leadership roles amongst students
Adapting the charrette process to the needs of the project	Learning new software (Elluminate) needed for communication during charrette night
Utilizing effective peer evaluations	

As shown in the table, one of the challenges that result from applying the charrette process to the academic setting from an instructor perspective is centered on the need to evaluate student learning. Similar to the challenges of utilizing TBL, determining student productivity and learning can be difficult when utilizing teams (Cestone et al., 2008). In TBL courses, individual student grade incentives for accountability are derived from four sources: (1) individual preparation, (2) collective preparation, (3) demonstration of how well knowledge is applied by individuals within a team, and (4) contributions to interpersonal group dynamics, team maintenance and productivity (Cestone et al., 2008). Therefore, Cestone et al. (2008) recommends using both a summative and formative approach to evaluate student performance.

One technique that is suggested is a peer assessment with both qualitative and quantitative questions on individual student participation.[13] Peer assessment forms can include sections where students numerically rate their teammate's productivity as well as a section for comments and explanation of issues. Peer assessment forms assist not only the instructor in evaluating individual contributions but also provide guidelines for addressing the student challenge of evaluating his/her peers. Lane[17] developed a "personal evaluation" form that can be given to students to evaluate each other on attendance, punctuality, behavior, respect, and preparedness based on a numerical scale. Below the numerical answers, comments are provided for each team member.[17] Another formative approach includes holding progress meetings and having the students complete and sign a "team timesheet" of their tasks. Although from a student perspective this may provide a challenge of keeping track of his/her work, it can promote a sense of individual responsibility when working with teams. In general, it is important to have summative as well as formative responses so that the data from the numerical responses can be used to ensure fairness in grading.[13]

Another challenge, which also could be considered a benefit, is the ability for students to define the design criteria that goes into the project. For example, if students are asked to redesign a real world plan, they can define the rigor of the design process as well as the inclusion or exclusion of design components. It is necessary to allow students to engage in real world open-ended projects that require them to define their own boundaries and guidelines. However, in doing so, the goals and objectives for the process have to be well-defined by the instructor to avoid students disengaging from the project. If the project is too open-ended they may not know where to begin and have difficulty in taking ownership. In contrast, if the project is too well-defined, then there is no creativity, self-discovery or exploration by the students themselves. Therefore, an equal balance between defining the scope and allowing for a real world open-ended project is recommended.[1]

Lastly, the class size can provide a challenge to the instructor in terms of maintaining small groups for the charrette night. Ideally NCI[8] recommends that the charrette process take place with a "small group". Therefore, having the students establish leadership roles within each team can allow for a small group of representatives from each team to share their design alternative based on input from all team members. This challenge of engaging all students during charrette night while maintaining a small group is discussed in more detail the following section.

APPLICATION TO CAPSTONE COURSE

In order to determine the feasibility of integrating a charrette process into engineering education, a case study is used. The case study focuses on the application of the charrette process into a senior level civil engineering design course at Lafayette College. This capstone course was developed around the need to enhance the college's athletic facility site, through sustainable design principles. Students were assigned to review an existing Master Plan for the athletic site, and develop a final Master Plan that includes a Sustainability Education Center as well as a number of additional sustainability components. Design criteria (plans, cost estimates, timelines, etc.) as well as specific sustainability design components (transportation, water, energy, agriculture, etc.) to be included in the final plan were provided to the students as a guide. This allowed for a defined project scope while allowing the students to explore the details of developing a real world sustainable Master Plan. There were 39 students enrolled in the course, with a variety of educational backgrounds ranging from civil engineering to art history and architecture. Since this course focused on two of the areas recommended for charrette application by NCI (Sustainability and Master Planning) and included students from diverse backgrounds, this course was ideal for a case study application of the charrette process. The following section describes the application of the charrette framework to the multidisciplinary capstone course.

Overview

In order to apply the charrette framework to the civil engineering capstone design course, the four adaptation areas for the charrette to be applied within an educational setting discussed previously (timeframe, participants, setting and environment, and instructor's role), were adapted and integrated into the course structure.

1) *Timeframe:* The timeframe was adjusted to the 14 week semester period with three weeks for Phase 1 (Research and Preparation), one night for Phase 2 (Charrette), and ten weeks for Phase 3 (Plan Implementation).

2) *Participants:* The participants included 39 students with the majority having background in civil engineering. The course was opened to those in the Engineering Studies program which have an interest in pursuing a cross-disciplinary degree with engineering and another discipline such as economics, business, etc. This unique characteristic allowed for a more realistic setting for the charrette process. The student backgrounds varied similar to typical charrette participants representing different stakeholder needs. The students were divided into three teams for Phase 1 and 2 based on backgrounds and disciplines. Phase 3 allowed for the students to organize themselves based on their own interests (transportation, agriculture, energy, etc.) for the detailed design process and plan implementation.

3) *Setting and Environment*: The course was located in the engineering building which is about three miles south of the athletic fields (location of site plan). Lecture sessions were held in a traditional engineering classroom, and a conference room was used for the charrette. Team work sessions were primarily held in computer laboratories and study rooms.

4) *Instructor's Role*: There were two instructors who acted primarily as liaisons throughout the project. They provided guidance and distributed project information to the students throughout each of the three phases. In addition, there was a charrette guide who assisted with the integration of the charrette framework into the design course. Information was presented to the students at the beginning of the course and guidance on resources and deliverables was provided throughout.

In order to explain the application of the charrette process in detail, the three phases of the charrette framework are discussed in depth as they apply to the course.

Phase 1: Preparation for Charrette

The first three weeks of the course were devoted to preparing the students for the "charrette night." The students were provided a syllabus describing the scope of the project as well as the goals for student learning. The eight goals directly relate to the ABET *Engineering Criteria 2000* for Criterion 3: Programs Outcomes and Assessment which are listed from A-K in Appendix D of *Engineering Change*.[15] The eight goals along with their associated ABET objective are shown in Table 3. As shown, the eight course objectives correlate to the ABET criteria for program outcomes and assessments with the goal of enhancing student learning throughout the capstone course.

Table 3- Course Objectives and Associated ABET A-K Criteria

Obj. #	Course Objectives (Provide experiences in…)	ABET *Engineering Criteria 2000*
1	Leadership and professionalism	**F**- Understand professional and ethical responsibility
2	Realistic civil engineering design	**E**- Identify, formulate, and solve engineering problems; **C**- Design a system, component or process to meet desired needs; **A**-Apply knowledge of mathematics, science, and engineering
3	Evaluate society's needs for constructed facilities and natural systems	**K**- Use techniques, skills, and modern engineering tools necessary for engineering practice; **H**- Broad education to understand impact of engineering solutions in a global and social context
4	Participate in various roles of a team	**D**-Function on multidisciplinary teams
5	Prepare and present accurate and well-organized written and oral engineering solutions	**G**- Communicate effectively
6	Recognize and respond to ethical, economic, environment, health, safety, and social factors	**J**- Knowledge of contemporary issues
7	Determine the life-cycle cost of a process and perform economic analysis of alternatives	**B**- Design as well as analyze and interpret data
8	Recognize their need for and opportunities in continuing education	**I**- Recognition of the need for and ability to engage in life-long learning

The 39 students were divided into three teams with the goal of developing a draft Master Plan for the athletic fields (one plan per team) that included a number of required sustainability components: renewable energy, composting, water management, and a sustainability education center. Optional sustainability components included: transportation, landscaping, agriculture, and art/heritage. Three teams were selected in order to maintain a maximum of three design alternatives for Phase 1. The large team size was managed by having team leaders established at the beginning who divided tasks amongst team members. The draft plans focused primarily on site layout including both the existing athletic facilities as well as the proposed sustainability component. The deliverable for Phase 1 was a printed, hard copy, computer drawn draft Master Plan for the athletic site for each team.

Throughout Phase 1, educational lectures were provided on project management, master planning, and a round table of the stakeholders involved in the project (including facilities managers, athletic coaches, etc.). In addition, a charrette preparation was held where the students were provided materials to make cardboard cut-outs of their design components based on the designated scale of the existing Master Plan. By having the students prepare cardboard cut-outs, they used them as puzzle pieces during the charrette night to help determine a final layout without having to redraw the components as the design changed throughout the night. This hands-on approach enhances the visualization and illustration of the proposed plan under discussion during the charrette night.

The students were also prepared for the charrette in terms of the computer technology selected for use during the charrette night. Since Phase 2 is most effective in a small group, [8] a web-based software called Elluminate, was chosen as a way for the students to see, hear, and chat with representatives of their group during the charrette night.[18] Therefore, the students were provided a tutorial session on Elluminate during Phase 1 to help them become familiar with the program features. The purpose and logistics behind the integration of the Elluminate program in the charrette process are further explained in the following section on Phase 2.

In addition to the technical aspects of preparing for the charrette night, Phase 1 allowed the students to become familiar with working with their colleagues and fostered team building skills. Over the course of the three weeks, the students began to take ownership of their design and accountability to their team.

Phase 2: Charrette

The second phase of the process is the charrette night where the students come together to share their draft Master Plans and come to a consensus on a final Master Plan that combines the strengths of the three teams. The charrette night was held on a Friday night at 8pm and continued until a final plan was agreed upon. It is recommended by NCI[8] that a "small group" be used to effectively facilitate a design charrette. Since each team had an average size of thirteen students, three representatives for each of the teams were nominated to start the charrette. The team representatives, who were rotated throughout the night, were located in a conference room and the remaining students were located in three classrooms throughout the building based on their three teams (Figure 2).

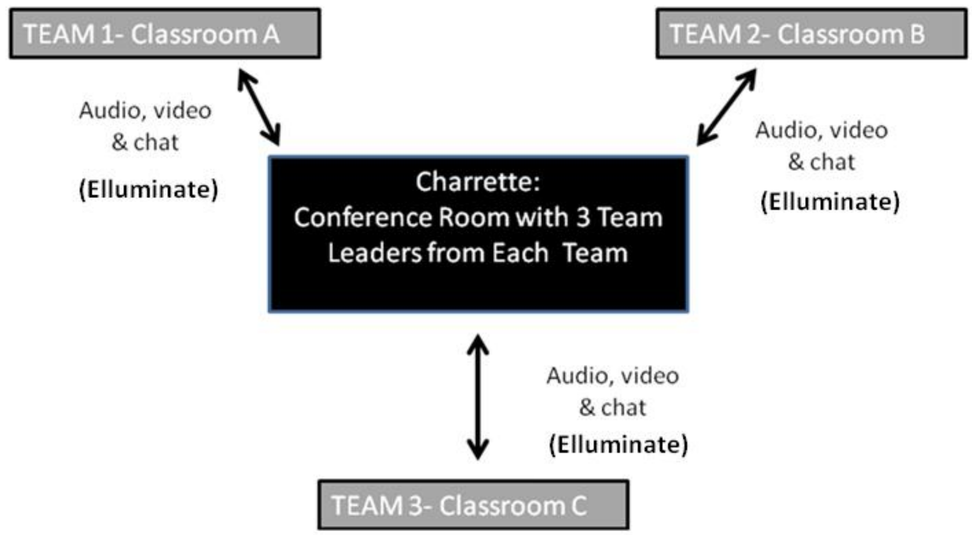

Figure 2- Layout of Charrette Night

In order to allow all students to participate in the charrette (from either the conference room or one of the three classrooms) the rooms were connected through video, audio, and online-chat functions using Elluminate. By using Elluminate, the students in the classrooms were able to view the charrette process and provide input to their team representative using the online-chat function. This increased student engagement throughout the charrette process while keeping the actual participants to a "small group". Throughout the night, the team representatives switched with other team members to increase participation. The general schedule for the charrette night was the following:

1) Team Overview (one hour) - each team summarizes their vision and overall objectives for their plan.
2) Hands-on Layout (unlimited time) - cardboard cut-outs are used as puzzle pieces on top of trace paper which is overlaid on a draft master plan to determine a draft site layout (Figure 3).
3) Consensus (unlimited time) - all team representatives agree on a final design for the Master Plan and trace the cardboard cut-outs of the design components on tracing paper.

Figure 3- Drafting Final Master Plan at Charrette Night

The charrette night lasted a total of five hours during which the three teams discussed the inclusion of individual design components, site layout, and the overall sustainability of the design. The students followed an iterative process of evaluating a number of alternatives and drafting design layouts using the cardboard cut-outs throughout the night. By the end of the charrette, the students agreed on a final draft Master Plan that was traced onto tracing paper which was overlaid on top of the existing Master Plan.

Phase 3: Implementation

After the completion of the charrette night, the students focused on implementing the Master Plan by working on the details of developing the individual design components. The students organized themselves into teams (3-4 students each) to complete the detailed design packages for the following components: athletic facilities, educational center, landscape and agriculture, composting, water management, transportation, and energy management. The detailed design packages included design plans, cost estimates, construction phasing, funding sources, and material selection for each component. By having the students organize themselves; students outside of the civil engineering program were able to contribute to the component that related to their area of study such as architecture or landscaping. In addition, three students were selected to serve as project managers with the task of holding progress meetings with the individual teams, developing progress reports, drafting the final plan electronically, and developing the final presentation/report.

Throughout Phase 3, guest lecturers were brought in to provide “expert” information and recommendations for sustainable design in the following areas: solar energy, wind energy, farming, landscape architecture, geothermal systems, etc. These experts served as contacts for students to ask questions and seek help regarding the detailed design.

The deliverables of Phase 3 included a full engineering report of the plan, current conditions, recommendations, and construction phasing. In addition, the last class was a presentation of the Final Master Plan (shown in Figure 4) to stakeholders of the project, members of the college, and community members. The purpose of the presentation was two-fold: to communicate the potential design to stakeholders as well as promote the integration of sustainable components into future development.

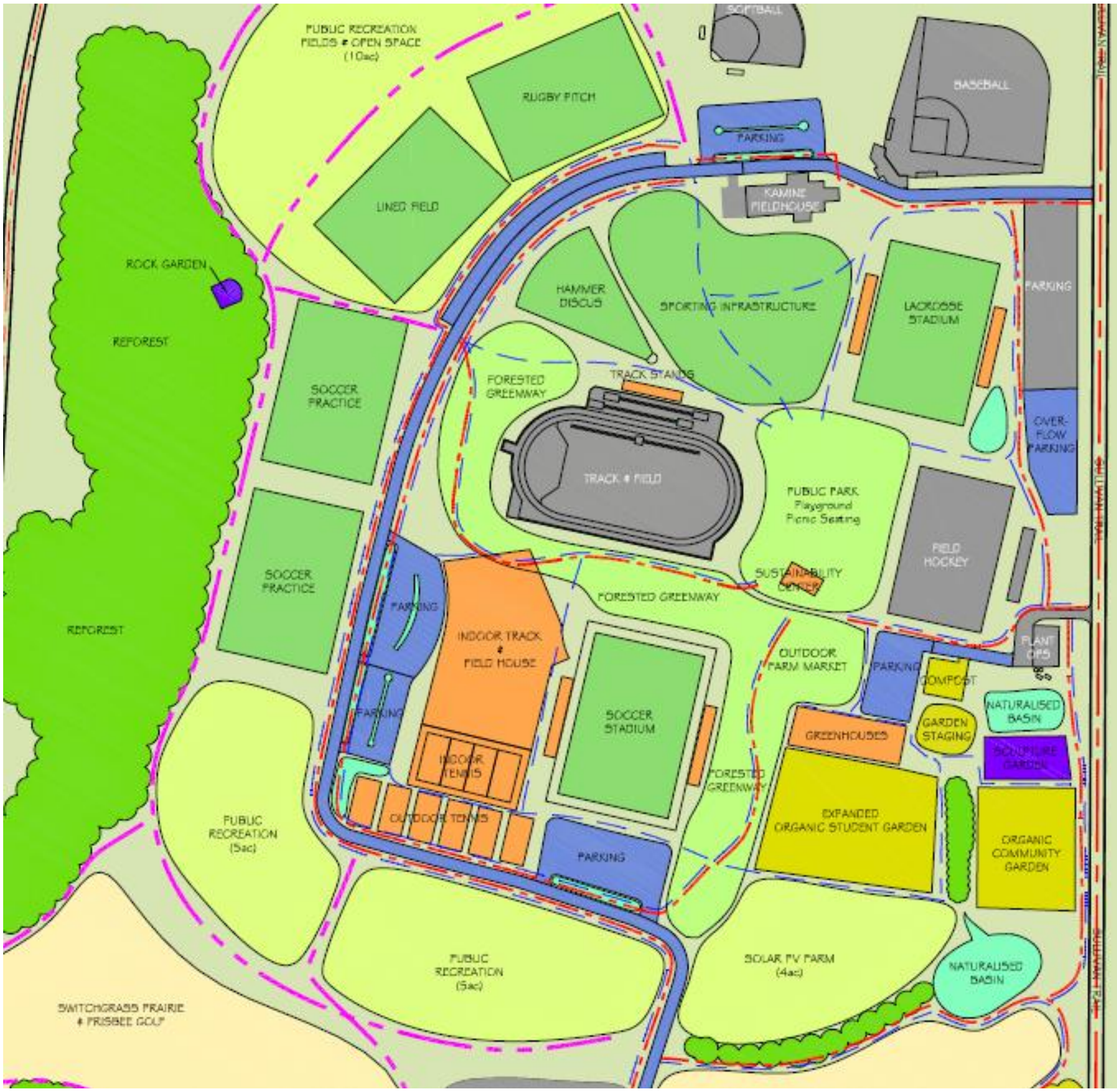

Figure 4- Final Master Plan Developed from Charrette Night

In terms of student evaluation, throughout the course, the students were required to keep timesheets of the tasks completed. This encourages students to be accountable and responsible for assigned tasks and promotes attendance at group meetings. Also, it improves the grading process by facilitating a fair, quantitative process for assigning individual grades. In addition, peer assessments were also used to rate the participation of team members. Each team member graded the remaining members based on their contributions to the team. This also improves fairness in the grading process since there are multiple assessments provided for an individual, in addition to their own timesheet.

RESULTS OF CASE STUDY

The case study of integrating the charrette application into the senior level civil engineering design course demonstrates that the charrette framework can be applied to an academic setting. Throughout the process, the strategies for a charrette framework identified by NCI[8] were directly integrated when applicable. Table 4 displays the correlation between the NCI strategies and their integration into the case study.

Table 4- Correlation between NCI Strategies and Case Study

NCI STRATEGIES	INTEGRATION INTO CASE STUDY
Work collaboratively	Three teams
Design cross-functionally	Design goal was to develop a sustainable yet functional plan
Compress work sessions	Compressed session into one night
Communicate in short feedback loops	Moderator
Study the details and the whole	Started with broad vision and then details discussed
Produce a feasible plan	Draft Master Plan developed
Use design to achieve a shared vision	Team visions were discussed first and included throughout charrette
Include a multiple day charrette	One night due to time constraints
Hold the charrette on or near the site	Held 3 miles from site

As a result of following the NCI process, the students were able to successfully combine three team Master Plans into one final draft Master Plan that represents the strengths of each team. The strengths of each team were evaluated by the students and a design consensus was reached based on cost, environmental impact and social equity of the design. During the charrette night, it was apparent that students took ownership of their plans and provided technical and practical evidence behind their design. This was apparent through the rigorous discussions back and forth over specific design components and the overall layout. Also, individual student perspectives played a significant role. For example, the student athletes provided an athletic perspective while those involved in the community garden provided an agricultural perspective. Also, the non-civil engineering students provided unique perspectives on the design process particularly in areas of architecture, landscaping, agriculture, etc. Therefore, by having the students select the teams for Phase 3, the strength of having diverse student backgrounds was highlighted in the final design.

Throughout the charrette, teams would disagree on placement or inclusion of specific design components, and then they would debate until a consensus was reached. For example, two teams agreed on the location of the soccer fields near the indoor track and field house. The third team wanted to relocate it to the south, in an existing open space area. After a long debate, a consensus was reached and the soccer field was placed adjacent to the indoor track and field house to improve access between the athletic facilities and to allow for existing open space to be used for public recreation. This is an example of how the charrette process allowed the students involved to evaluate multiple alternatives and reach a consensus toward the "best" sustainable design.

At the end of the semester, course evaluations were used to determine the effectiveness and overall benefit of the capstone course to student learning. Since this was the first time the course was taught and since it incorporated innovative design principles such as the charrette process, specific questions were asked regarding course content. Each of the questions included in the evaluation directly relate to the original eight course objectives provided in the course syllabus which are linked to the ABET *Engineering Criteria 2000* A-K objectives (shown in Table 2). The average student responses were based on the following grading scale: A = Excellent, B = Very Good, C = Good, D = Fair, E = Poor, F = Very Poor, and G =Don't Understand Question. The results showed that almost all of the objectives were addressed at the Excellent level ("A") except for Objective #7 (lifecycle assessment and economic analysis) which had a "Very Good" rating. The results (Table 5) are based on a total of 31 student responses out of a total of 39 students in the course, which is about an 80% response rate.

The first three questions focus on the charrette process and are used to understand the student's perspective on the integration of this process. Although the terms TBL and PBL are not explicitly defined, the questions can be tied to key components of these learning models. For example, question #1 relates to the objectives of team roles and leadership. Questions #2 and #3 relate to the goals of real world problem solving. Feedback on the details of the charrette process including instructor guidance, guest lectures, and course structure were also gathered through instructor evaluations.

Table 5- Course Evaluation Results Correlated to Course Objectives

Course Evaluation Question: To what extent …	Average Grade	Summary of Related Course Objectives	ABET Criteria
1. Was the charrette process helpful in sharing ideas and understanding the perspectives of other teams?	A	#1- Leadership, #4- Team Roles	F and D
2. Was the charrette process useful in allowing the class to come to a final collaborative Master Plan?	A	#2- Realistic civil engineering design	E, C, and A
3. Was the charrette process a valuable experience in terms of integrating a practical design application into a class?	A	#2- Realistic civil engineering design	E, C, and A
4. Has the course provided opportunities to evaluate society's needs for constructed facilities and natural systems and to design systems, structures, processes, or conditions to meet those needs while protecting the environment, conserving resources, and maintaining quality of life?	A	#3- Evaluate society's needs for constructed facilities and natural systems	K and H
5. Has the course provided opportunities to recognize and respond to ethical, economic, environmental, health, political, safety and social factors in decisions that affect project completion, analysis, design, construction, operation, and conduct of duties?	A	#6- Ethical, economic, environmental, health, political, safety, and social factors in decision making	J
6. Has the course provided opportunities to participate in various roles of a team whose function is to define, analyze, and synthesize a solution to an open-ended design problem and to understand that problem's relevant multidisciplinary aspects and contemporary issues?	A	#4- Team roles	D

7. Has the course provided opportunities to prepare and present accurate and well-organized written and oral engineering solutions, designs, or plans that are appropriate for a particular audience?	A	#5- Written and oral engineering design solutions	G
8. Has the course provided opportunities to determine the life-cycle cost of a process, component, or system and perform an economic analysis of alternative, feasible solutions for a project?	B	#7- Life-cycle cost and economic analysis	B
9. Has the course provided venues and opportunities to recognize their need for and opportunities to engage in continuing education through their career?	A	#8- Continuing education	I

As shown by the course evaluation results, the students felt that the course was successful in meeting the course objectives. In terms of the charrette component, the students answered "Excellent" to all three questions that specifically targeted its integration. Therefore, this suggests that the integration of a design charrette into a capstone course can enhance student learning and promote opportunities for leadership, practical design experience, teamwork, communication, and professionalism.

Although student evaluations represent the students' perception of the course, they are an indicator of student achievement through the course. The instructors' evaluation of the course support the findings of the student evaluations based on the project deliverables, student participation, stakeholder input, and quality of the final design. Since the final design was presented to the stakeholders involved in the project, there was a third party assessment of the final deliverable which serves as another form of course evaluation. These three assessments combined provide a rigorous evaluation of the course as meeting the project goals.

In terms of challenges, there was one point in the process (Phase 3) where the project managers were given the responsibility of overseeing the progress of the entire class. In Phase 3, the instructors served as liaisons and provided resources when necessary. The three students who were selected as project managers were faced with trying to keep the class on track in terms of timeframe and purpose. Luckily, the project managers were able to gain a sense of authority with their role through determining the schedule, assigning tasks, and gathering information for the final product; however, this can be hard to achieve.

Another challenge was determining the design criteria for the entire semester at the beginning of the course, without knowing student involvement or interest in the project ahead of time. Therefore, even though the general design criteria were established for the course, the design criteria were re-evaluated prior to the implementation of each phase. For example, after Phase 2 concluded, the design criteria for Phase 3 were revised based on student input, needs, and involvement. This allowed for an iterative process for revising the design criteria.

In general, the results of the design charrette integrated into the civil engineering capstone course proved to be an advantageous process that promoted student learning, responsibility, and leadership. The final product exceeded the faculty's initial expectations of the teams' work product. Since the project was focused on a real world design at the college, the instructors provided necessary contacts related to the project including facilities, transportation, athletics, administration, etc. This allowed for students to have access to the details necessary to develop a feasible design plan. Also throughout Phase 3, progress report meetings with the instructors and the teams were held to address any design challenges throughout the process. The high quality final plan was presented to the stakeholders as a design alternative that could be implemented as soon as funding was achieved.

CONCLUSION AND RECOMMENDATIONS

Students respond positively to real-world design problems. Student buy-in toward design projects is enhanced through ownership. In order to maximize the outcome of capstone design, incorporating a real-time, iterative design process that incorporates team acceptance of one comprehensive design has proven successful. Integrating a design charrette process into engineering design courses is not only practical, but also self-rewarding for each student involved. The students begin with unique perspectives on a common plan and work through the challenge of coming to one comprehensive design that draws on the strengths of each perspective.

Use of a design charrette was particularly valuable in terms of enhancing TBL where students have to work with each other to come to a successful design that represents a variety of perspectives. The charrette is also useful in developing insights based on peer evaluation, as suggested by student evaluations from the case study. Providing a formal process for reviewing, commenting on, and evaluating the contributions of fellow students facilitated insights by students into their own contributions.

Adjusting the charrette process for the purpose of an academic setting provides significant short and long term benefits to student learning. The case study on a civil engineering capstone course provides evidence of the strengths and challenges of the process. The results of the student evaluations indicate that from their perspective, the project goals and ABET learning outcomes were achieved as a result of the adapted charrette framework. The instructors' evaluation of the course support this conclusion based on the project deliverables, student participation, stakeholder input, and quality of the final design. Future implementation of the charrette process in capstone courses, similar to the case study, can allow students to not only gain technical design skills but also to foster skills in communication, technical evaluation, teamwork, peer-evaluation and professionalism.

Since engineering education research is an iterative process, it is recommended that future case studies on the charrette framework be implemented for further refinement. In addition, there are some improvements that can be made in future application. Recommendations are provided as a way to enhance future applications of the charrette process into engineering capstone design courses.

One improvement is related to the challenge of having the students define the design criteria in a way that allows the project to be open-ended without being too vague. As stated previously, an open-ended problem allows students to define their own boundaries and guidelines for how detailed they want to embark on the real world design process. It is recommended that the design criteria be developed by the students in Phase 1 with minimal guidelines provided by the instructor.

Another improvement would be to clarify the roles of the students during Phase 3 (Plan Implementation). Once the students were divided into teams for the detailed design packages, the three students who became project managers had the challenge of leading the entire class. In order to aid in this process, the instructor should have a list of required tasks that is associated to with each student role. By doing this, the position of project manager is clarified ahead of time and the other students will not be able to question their authority. Once authority is established, the remaining students can meet their own responsibilities and understand their contributions to the overall goal.

Another recommendation for the course in regards to grading is that it would be ideal for all faculty and project managers to meet and talk about the outcomes of the group final projects. Due to time constraints however, this typically does not happen in a meaningful and productive way such that students benefit from the comments and suggestions. Therefore, in order to address this, it is recommended to move the deliverable dates to earlier in the course to allow for a review stage. This will provide the opportunity for students and faculty to evaluate the outcome and make changes if necessary. With the incorporation of these improvements, the design charrette process can improve the traditional design course.

Ideally, the integration of the charrette process can be utilized to enhance student learning in a variety of capstone courses as a way to replicate the real world design process and prepare students for the practice of engineering.

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