Assessing the Impact of the Concrete Canoe and Steel Bridge Competitions on Civil Engineering Technology Students

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Abstract

The new accreditation criteria (TC2K) of the Technology Accreditation Commission of ABET require an assessment of Program Intended Learning Outcomes. Some of the learning outcomes required by the "a" through "k" and the Civil criteria of TC2K include leadership skills, teamwork skills, project management skills, communication skills, and design and construction skills.

The American Society of Civil Engineers (ASCE) and the American Institute for Steel Construction (AISC) sponsors regional and national concrete canoe and steel bridge competitions on an annual basis. The Civil Engineering Technology (CET) students at the Rochester Institute of Technology (RIT) have participated in these competitions for the past nine years. These competitions give students a chance to apply what they have learned in the classroom.

To assess the impact of the concrete canoe and steel bridge competitions on student learning and development, the authors carried out a survey of current students and graduates of the CET program at RIT who have been members of the concrete canoe and steel bridge teams. The issues addressed in our survey include the following: impact of these activities on leadership skills, communication skills, teamwork skills, design and construction skills, project management skills, confidence levels, students' enthusiasm for the profession, and a positive image and exposure for students and CET programs.

In this paper, we discuss the results of this survey and some of the challenges to student participation in these non-credit activities at RIT, and present some suggestions for enhancing the level of student participation.

Introduction

The new ABET criteria requires engineering technology students to develop a certain set of skills at the time of graduation; these skills include design, communication, teamwork, project management and leadership.[1] One way these skills could be acquired and enhanced is by participation in student project teams such as the concrete canoe and steel bridge teams and competitions. The American Society of Civil Engineers (ASCE), Master Builders, Inc., and the American Institute of Steel Construction sponsor these competitions annually. Approximately

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200 teams from civil engineering and civil engineering technology programs across the US and Canada participate in 20 regional competitions.[3]

At RIT, the concrete canoe and steel bridge teams exist within the ASCE student club. The main focus of the club is on professional development, engineering ethics, hands-on learning, and community service. Both the concrete canoe and the steel bridge are yearlong projects that begin in September and culminate in a regional competition in April, and a national competition in June. The student design teams at the RIT consist of undergraduate students in their first through fifth year of study.

The new Engineering Technology Criteria of ABET, ET2K, as well the Engineering Criteria EC2000, now require continuous assessment of all program activities to ensure that the program outcomes and educational objectives are being met.[1, 2] To assess how well the concrete canoe and steel bridge teams meet the ET2K requirements, and to quantify the effect of project teams on students' skills development, the authors carried out a survey of students and alumni of the Civil Engineering Technology program at RIT. The survey was also used to determine why more students do not participate in the student project teams, and to find ways to increase student participation in these activities.

The survey was sent out to all Civil Engineering Technology students at RIT and to alumni of the CET program who were previously members of the canoe or steel bridge teams. The survey instrument used is shown in Appendix 1. The results of the survey are divided into two groups: participants in the student teams and non-participants. In this paper, the authors present a summary and discussion of the survey results, and discuss the workings of the steel bridge and concrete canoe teams as well as recommendations for enhancing student participation in the project teams.

Steel bridge project team

The steel bridge team is an avenue for students to apply the skills that they learn in the classroom to a real-life project. It is a collaboration of students that work together to fabricate a $1/64^{th}$ scale steel bridge to compete in the American Institute of Steel Construction Student Steel Bridge Competition. Students must follow strict rules on bridge dimensions, maximum deflections, bridge loading, safety, and construction limitations. The steel bridges are judged in three main categories: weight, deflection, and construction speed. The best bridge in these three categories that does not violate any of the parameters stated in the contest rules ultimately wins the competition.

Each year the RIT bridge team begins its concept phase in September. At this time, students brainstorm and compare alternative designs using commercial structural analysis/design software with the aim of producing a design that is structurally efficient and easily constructible; this preliminary design phase usually extends well into December. The member-to-member connections, which are critical to achieving a fast construction speed, are fleshed out at this time. This preliminary design phase is the most important part of the process. In this phase, the students use their problem solving abilities to develop an acceptable design. It is vital that they

be able to communicate these design ideas to their fellow students and stand the critique of these ideas by their peers.

Fabrication of the bridge begins after a design has been chosen. Students estimate and order the steel needed to build the design. Often times, the member-to-member connections are revised and fine tuned while the actual fabrication process is in progress, as is often the case in real world projects. Good teamwork skills are essential in this phase of the project, as students must work together to drill, machine, and weld their bridge together.

After the bridge has been fabricated, the next issue the team tackles is the assembly process. The team members must determine how many builders are needed and where they must be stationed for timed construction. The steel bridge must be assembled as quickly as possible without violating any of the stated contest rules; the intent is to avoid penalties as much as possible. For example, if a team member steps into the imaginary river, the team is penalized heavily as this is tantamount to drowning. Teams are also penalized by an increase in their construction time if any mishaps occur during the competition, such as dropping a bridge bolt or a team member's hardhat falling off. These penalties are included in the competition rules in order to maintain safety at all times and to simulate and emphasize the real-life consequences of construction accidents. After builder placement has been decided, the team then practices their assembly.

Throughout the process of construction, the materials used for fabrication are purchased with funds that are raised by the students. Each year letters are sent out to local businesses soliciting funds to purchase the required materials and finance the travel expenses for the competition. This letter is usually co-signed by the faculty advisor and the team captain. The total annual expense varies from year to year depending on the design and the number of students participating in the competition. The average material cost for a steel bridge at RIT is approximately $ 800. Approximately $100 per student is required for travel expenses to the regional competition. The number of steel bridge team members that travel to the competition can vary from ten to fifteen, though only about eight team members or less typically participate in the timed construction.

The steel bridge team at RIT takes special pride in the fact that the fabrication of their bridge is completed in-house solely by the students. It is permissible in the rules of the competition for student bridges to be built by an independent contractor. The students in the steel bridge team at RIT choose to build their bridges by themselves year after year. This is because of a genuine desire to acquire and develop hands-on experience during the complete design-build process. Additionally many students exhibit an equal interest in the construction as well as the design. During the fabrication process safety is always paramount and stressed at all times. When welding, drilling, and grinding of materials, the students are required to wear personal protection equipments such as goggles. Upon completion of the fabrication phase, the students feel a sense of accomplishment, because for the first time all of the ideas from the team have become a physical reality.

Concrete canoe project team

The concrete canoe team focuses on the design, fabrication, racing and presentation of a canoe made entirely of concrete. The competition, attended by more than 100 teams from different schools around the United States, Mexico and Canada, is sponsored by the American Society of Civil Engineers and Master Builders, Inc. The National Competition committee develops strict rules for the teams to follow. These include restrictions on the materials, aggregates, concrete, filler, reinforcing, finishing, equipment, and safety. The rules also outline all of the academic requirements necessary for entry into the competition.

The team begins the design of the hull and the concrete mix in September. The concrete mix is designed using admixtures that allow the unit weight to be lighter than that of water. In order to qualify for competition, the canoe must be able to float after being completely submerged in water. The main criteria are to design a mix with appropriate workability that is lighter than the unit weight of water and strong enough to withstand the stresses induced on the canoe during the competition. The compressive strength of the concrete must be high enough to withstand the weight of four people with a hull thickness of less than one-half inch. Developing the proper mix to ensure a durable and buoyant canoe is perhaps the most challenging part of the competition.

Throughout the entire construction process, it is important that all safety regulations be adhered to. Many of the admixtures in the concrete mix are potentially harmful if used carelessly. Students wear personal protection equipment such as gloves, goggles, and respiratory masks when handling all harmful admixtures. Classes are in session, using much of the same equipment, and share the work area with the concrete canoe team, making it very important to maintain cleanliness and proper storage of all materials for the safety of everyone.

The competition has four main categories. These are finished product, oral presentation, technical paper, and canoe races. The finished product is judged on aesthetic appeal, finishing techniques, and durability. A technical paper six pages long must be submitted to the judges prior to the competition. An oral presentation of the paper is scheduled for the day of the competition, followed by questions from a panel of judges. The real-life application and durability of the canoe is tested as the teams compete in five races. These include both male and female sprint and distance races, as well as a co-ed sprint. A combination of the team's scores in each of the four categories determines the final ranking of the team in the competition.

Each year, students are challenged to create a better canoe than the year before. This includes producing a mix that is lighter and stronger, a hull that is more efficient in water and developing better construction techniques. Using ideas from previous years as well as their own ideas, students solve the problems set forth by the competition committee in a professional manner.

Another major aspect of the concrete canoe project is fundraising; the teams raise funds to cover the cost of materials and travel expenses, and beginning in September, members get together to create a list of local businesses from which funds are requested. A letter that is co-signed by the faculty advisor and team captain is sent to prospective sponsors and the team members follow up

these letters with phone calls. The team's supply "wish lists" are brought to local hardware stores where many items are either donated or discounted. In addition, the student teams have done fundraisers such as selling T-shirts and review books for the Fundamentals of Engineering Exam. The construction of the concrete canoe is estimated to cost approximately $1500 in materials alone. Depending on the location, the regional competition costs can be up to $600 for the transportation of team members and a rental truck to ship the canoe. Also, depending on the size of the team, overnight accommodations average up to $500. If the team continues to National Competition, the costs are much higher depending on the competition location.

Quantitative analysis of the survey results

The survey was carried out to determine the impact of the Concrete Canoe and Steel Bridge teams on the personal development and skills of the team members. The survey instrument used is presented in Appendix 1. Out of a total of 80 surveys that were mailed to CET alumnae who were previously members of the concrete canoe or steel bridge project teams, 24 surveys were returned. Additionally, surveys were handed out in class by the CET faculty to current CET students, and a total of 76 student surveys were returned. Of the students surveyed, approximately 67% responded that they had no involvement in the concrete canoe or steel bridge teams and therefore will be classified as non-participants in this paper. About 33% of those surveyed indicated some level of involvement and these are classified as participants in this paper. Only 3.5% of the total surveyed group considered themselves actively involved, while 15.5% said they were very involved, and 13.8% claimed to have some involvement. An average value of the ratings for participants and non-participants was determined for the different skills measured. The results of the survey as depicted in Figure 1 shows that students who participated in the concrete canoe or steel bridge teams consistently rated themselves higher in all of the personal development categories and professional skills addressed in the survey than the students who do not participate in these teams.

The difference in the ratings between participants and non-participants, measured as a percentage of the non-participant rating, can be grouped into three distinct ranges.
The most significant difference in ratings, which ranges from 12 to 14%, occurs in the teamwork skills and job search opportunities categories. A moderate difference in ratings of between 8 and 9% occurs in the following categories:

- Oral communication Skills (9%)
- Leadership Skills (8%)
- Project Management Skills (8%)
- Positive Exposure and Image for RIT CET students (8%)

The smallest difference in the ratings between participants and non-participants is about 3 to 5% and occurs in the following categories:

- Personal level of Confidence (5%)
- Enthusiasm for the Civil Engineering Profession (4%)

- Written Communication (3%)
- Design and Construction Skills (3%)

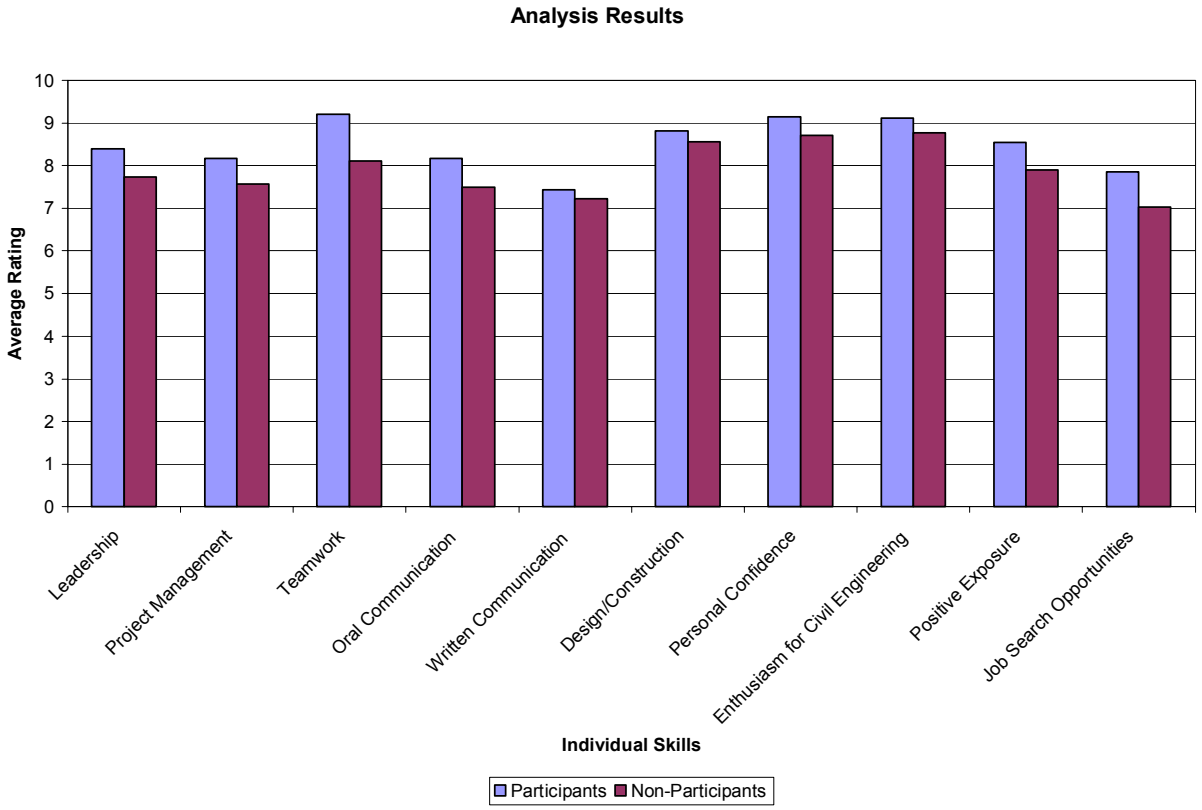

Figure 1

Assessment and development of skills

The results of the survey indicate that participation in the concrete canoe and steel bridge teams enhances leadership, project management, teamwork, design and construction, and communication skills. Students learn and develop these skills as the projects progress from the drawing board to the finished product. It is the authors' opinion that these skills are enhanced by student participation in the project teams.

Leadership ability is arguably one of the most important skills that an engineer should possess and develop.[4] The design teams encourage students to take on roles that enhance leadership abilities. During the course of the project's design and construction, it becomes necessary for one or more students to take on significant responsibilities such as chairing meetings, motivating team members, delegating responsibilities and educating newer members on design concepts as well as construction procedures and techniques. These responsibilities are not limited to the team captains. Many team members take on leadership roles in one form or another as they participate

in the design, construction and competition. Both teams strive to give every student an opportunity to lead a subgroup assigned to a specific task. Whether it is acquiring material for the steel bridge or constructing the canoe mold, every task is critical to the successful completion of the project. Completing tasks correctly and on time enable the students to develop confidence in their abilities to lead a team.

Project management is a prominent career track for civil engineers. Therefore, it is important that students acquire some project management skills and experience prior to graduation. Both the steel bridge and concrete canoe teams offer the opportunity for students to develop and enhance these skills. Funds allocated to both teams must be managed prudently and appropriated judiciously. In the case of the concrete canoe team, the specifications require the creation of a detailed cost estimate for the design and construction of the canoe. The students develop a cost analysis for material costs, labor, and project management. Design schedules are created and followed. Due to the complexity of the tasks that take place in a short amount of time, a detailed construction schedule must also be created. It is the responsibility of the students to ensure that the schedule is reasonable and adhered to; however, a certain amount of flexibility is required as last minute changes call for smart thinking and quick action. All of these tasks create a good environment for students to acquire and hone their project management skills.

Good teamwork skills are essential for the success of the concrete canoe and steel bridge design projects. Almost all phases of the design and construction involve some form of group work, which mimics settings that students are likely to see in the workplace. A diverse group of students have to work towards a common goal, and as with any group, the teams experience many conflicts between members. Personality conflicts arise as students work together under stressful time constraints and tight work areas. Different skill levels among the members can delay progress; therefore, patience and an aptitude for learning are necessary from everyone involved. Overcoming these obstacles fosters a sense of unity and accomplishment. Students also develop good sportsmanship skills as they participate in an intensely competitive process. There have been occasions during the competition when the judges have interpreted the rules in a way that the team felt was unfair or incorrect; however, the team members stayed calm and accepted the judges' decision with respect and magnanimity. The good sportsmanship skills of the team and the leadership skill of the team captain were clearly evident as he explained to his teammates why they must accept the results calmly. Students will need these sportsmanship and teamwork skills as they move into the competitive world of business.

Design skills are essential for the concrete canoe and steel bridge teams. Both teams require students to design and construct the product or structure according to a given set of specifications. Students must be creative in their designs in order to be as cost efficient as possible and to avoid violating the specifications; this avenue for creativity in an engineering project is very difficult to duplicate in the classroom. Students apply the techniques and concepts learned in the classroom, including hand calculations and computer software in the design of both projects. The canoe and bridge teams spend about half of their time on design functions.

The student team members complete the construction of the canoe and the steel bridge in-house. Team members usually engage in self-study, beyond what they've been taught in class, to bring themselves up to speed with the techniques and concepts that are required to design the project; this process of self-study enhances their critical thinking and life-long learning skills. Students acquire hands-on experience in the use of construction tools like welders, power saws and grinders. The load testing of the steel bridges during the competition is a unique opportunity for students to observe the behavior, and sometimes failure, of structures under load. There have been occasions during the competition where some bridges have collapsed while being load tested, and that has been an unforgettable experience for the students as they analyze and discuss the possible reasons for the structural failure; such practical experience is difficult to duplicate in the classroom and is invaluable in helping prevent such structural failures from occurring in practice.

It is important to note that during both the design and construction of each project, younger and less experienced members are able to interact with veteran team members. Design and construction that starts from scratch every year serves as an excellent opportunity for senior members to teach newer members the necessary techniques. This blending of skill levels is important in order to pass on skills as older students graduate and newer members join the team. Consequently, a first or second-year student on the steel bridge team will have a better understanding of some structural concepts than non-participants even before they are introduced to the concept in the classroom. On the other hand, veteran team members benefit from the new team members as they bring fresh and new perspectives and ideas to the projects.

Strong written and verbal communication skills are necessary for success in the engineering industry. While an engineering curriculum is geared towards technical and theoretical skills, it is necessary to develop an aptitude for effective communication. To be successful in the concrete canoe or steel bridge competitions, students need to be able to express their ideas clearly, both written and orally. For example, the canoe team is required as part of the competition to submit an overview of the canoe design and construction in both written and oral formats. The presentation of oral and written reports is included in the final score for the competition. Furthermore, if students expect new ideas to be successfully implemented, they must learn to articulate those design concepts verbally to their teammates, and by conveying their thoughts clearly, the design and construction process can then proceed at an efficient pace.

Assessment of students' personal development

The results of the survey indicate that participation in the concrete canoe and steel bridge teams enhances the students' confidence in their abilities, their enthusiasm for the civil engineering profession, job opportunities for students, and provides a positive exposure for the RIT Civil Engineering Technology program.

The design teams require a significant time commitment from team members. The team-oriented nature of the projects allows many opportunities for interaction amongst students and networking; as a result, mentor/protégé relationships develop. It is a commonly accepted fact that freshmen students who have mentors excel in both academic and social skills. The steel

bridge and concrete canoe teams is an avenue for students to acquire this academic advantage. This study revealed that the average GPA of participants in the student teams is about 3.26 while that of all CET students was 2.90 for the same quarter. The difference in GPAs can be attributed to students applying skills learned through participation on the teams to class work.

The younger students involved with the team learn some of the techniques used in upper level design courses such as free body diagrams, while developing innovative hands-on connection details and construction techniques. Members of both teams develop a great deal of confidence in their abilities as they meet the challenge of designing and building a bridge or canoe, despite the heavy burden of schoolwork. When the project is successfully completed on time and performs well at the competition, that sense of confidence is greatly enhanced; the students realize that they can compete at the same level with any civil engineering or civil engineering technology program in the country.

Students should be enthusiastic about their chosen field, be it engineering or any other academic pursuit. The concrete canoe and steel bridge team members appear to have a higher sense of and much more visible degree of enthusiasm for the civil engineering profession. This stems from being part of a successful team and working on real-life projects where a product or structure is actually built and tested. Once the steel bridge or concrete canoe for a particular year is completed, students almost immediately begin working on ways to improve the finished product or structure for next year's competition. This constant desire of the students to improve on their design and construction techniques carries into their work place when they go on co-op or when they graduate. The students that are involved with the project teams understand that the topics and concepts they learn in the classroom are applicable to real world problems and are anxious to utilize their newly learned skills during co-op placement or in full-time employment after graduation.

Team members appear to have more job opportunities available to them as a result of the hands-on experience acquired from working on the projects and the networking opportunities and exposure to potential employers at the national competition. Job opportunities are also available through the many project team sponsors and consultants that assist with tools, materials, donations, and industry insight. As the students and professionals work together on a project like the steel bridge or concrete canoe, the opportunity to develop a professional relationship with the practicing engineer is enhanced. These professionals have the opportunity to discover the work ethic, knowledge, and personality of the students; the students in turn have a great opportunity to impress a potential employer. This student-practitioner interaction through the canoe/bridge teams can act as an informal interview for employment for the student.

The concrete canoe and steel bridge teams enhance the visibility of and respect for the Civil Engineering Technology program within the institution as team photos and competition results appear in the school newspaper. Frequently, students and faculty from other departments express interest in becoming involved with these projects. This positive exposure also extends into the Greater Rochester community. The local newspapers and TV stations have reported on the teams' success. This positive exposure of the project teams generated by the news coverage

attracts new student team members and potential donors and sponsors, thus generating additional funds for the RIT Civil Engineering Technology program.

Student participation in project teams

The third section of the survey included three questions that focused on factors that discourage students from participating in these teams and how student participation can be enhanced. The response to the questions in this section from project team participants and non-participants are discussed below. Almost every one surveyed responded to the first two questions in this section while only 3% responded to the third question.

The first question in this section of the survey solicited reasons why more students do not participate in the project teams. The most common response to this question was that students do not have the time to participate given the heavy burden of schoolwork and the short and intensive ten-week quarters at RIT. Many of the participants in the design teams also work on a part-time basis; clearly, students who are unable to participate in these student team activities because of other obligations are at a disadvantage given the many skills that students can develop by working on these projects. In addition, the majority of the third to fifth year students are absent while on internship, or co-op, for at least one of the three quarters each year making it difficult to have a consistently dedicated group of students. For many students, the pressure of classes, in addition to part-time or full-time employment, and participation in extra-curricular activities is too much to bear.

The second most common response was that there was not enough advertising of the clubs and therefore many students are unaware of the project teams. The ASCE Student Club advertises its weekly meetings, but perhaps the methods used such as email, which are sent only to students that already participate on the teams, and fliers that are placed in areas around the Civil Engineering Technology offices may not be very effective.

The second question solicited ideas on what could be done to increase student participation in the project teams. The most common response to this question was that the CET faculty should cut back on the workload so that students can have more time to participate in the project teams. It is the collective belief of the authors that the CET faculty at RIT is already doing their best to present the necessary course material in the most effective way possible without over burdening the students. However, it may be beneficial to students for the ASCE student club to offer a seminar on time management. The second most common response was the suggestion that course credits be awarded for the canoe and bridge projects; many of the alumni surveyed recommended making each of the project teams a one-credit independent study course. The students and alumni surveyed argue that awarding course credit for the projects would increase participation because the students will have the added incentive of knowing that the time spent on these projects is rewarded in a tangible way on their transcripts. The United States Military Academy at West Point has already adopted this idea for its steel bridge and concrete canoe projects. The third most common response was for more effective advertising of the project teams. Some examples of effective advertising that was proposed include the following: hanging more fliers, having team members become more actively involved in campus-wide

activities, such as displaying the canoe and steel bridge during open houses at which CET freshmen and transfer students can become more acquainted with the concrete canoe and steel bridge project teams.

Conclusions and recommendations

The authors have presented the results of a survey of students and alumni for the purposes of gauging the level of student participation and the effect of project teams on student skill development. The survey results indicate that students who participate in the project teams consistently rated themselves higher for all the different skills measured in the survey than non-participating students, thus confirming the importance of student project teams.

We also received several ideas from the surveys for enhancing student participation in the student project teams. To enhance student participation in project teams, more creative ways for advertising the meetings of these project teams should be developed so as to reach a wider segment of the CET students in the program. The CET faculty should be encouraged to make periodic announcements regarding the project teams in their classes. Additional advertising should include CET faculty members inviting the concrete canoe and steel bridge team captains to their classrooms to make five-minute presentations on the project teams to their students. Another recommendation is for the team members to become more actively involved in campus-wide activities such as graduation, open houses, and homecoming weekends to improve the visibility of the concrete canoe and steel bridge teams. We also recommend that the concrete canoe and steel bridge projects be converted into one-credit independent study projects in order to enhance student participation; this approach has been adopted by the United States Military Academy at West Point. To ensure that team members put in an adequate and equal amount of effort, students should be required to keep a written record of the time spent on the projects and to submit peer evaluation reports at the end of the project.

In this paper, the authors have shown that student participation in the concrete canoe and steel bridge projects enhances the skills and personal development of the students involved. The CET program at RIT plans to use the ideas generated from this study for the continuous improvement of the design project teams and to enhance student participation, thus "closing the loop" with regards to the ABET TC2K. It is the authors' hope that the ideas presented in this paper can be used as a tool by other CET programs and institutions to enhance student participation in the concrete canoe and steel bridge project teams.

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Appendix 1

SURVEY OF RIT CET STUDENTS & ALUMNI

Dear CET student or graduate,

The CET department is trying to assess the impact of the concrete canoe and steel bridge competitions on student learning and development. We are asking that you please take some time to fill out this questionnaire. *Please complete the survey only once!* We thank you in advance for your participation.

Are you a current or former member of the concrete canoe or steel bridge team?

Yes No

Please rate your involvement in the concrete canoe or steel bridge team:

None Some Involvement Actively Involved Very Involved

Are you involved in other student organizations or clubs on campus?

Yes No

Circle one answer for each of the following, with 10 being the most positive. Please answer according to skills you have acquired throughout your experience at RIT *whether or not you were involved in the concrete canoe or steel bridge teams*.

Leadership Skills	1	2	3	4	5	6	7	8	9	10
Project Management Skills	1	2	3	4	5	6	7	8	9	10
Teamwork Skills	1	2	3	4	5	6	7	8	9	10
Oral Communication Skills	1	2	3	4	5	6	7	8	9	10
Written Communication Skills	1	2	3	4	5	6	7	8	9	10
Design and Construction Skills	1	2	3	4	5	6	7	8	9	10
Personal Level of Confidence	1	2	3	4	5	6	7	8	9	10
Enthusiasm for Civil Engineering Profession	1	2	3	4	5	6	7	8	9	10
Positive Exposure and Image for RIT CET Students	1	2	3	4	5	6	7	8	9	10
Job Search Opportunities	1	2	3	4	5	6	7	8	9	10

What do you feel discourages students like yourself from participating in such activities as the concrete canoe and steel bridge?

What could be done to increase the likelihood of your participation in student activities?

Please provide any additional comments that you may have on reverse side.