Analysis of the Trinity College Walk-on-Water Project: a Case Study of Team Learning in the Design Experience

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Abstract: Although a substantial history exists regarding the use of team projects as instructional activities in engineering design curricula, only limited attention has been given to project subjects that span multiple areas of engineering, including biomedical, civil, electrical and mechanical. The conceptualization of such topics, and their integration into the broader curriculum, involves appraisal of important questions relating to prerequisite knowledge, integration of disciplines, learning by design, teamwork, competitions, assessment and evaluation.

As an example of one such extensive project, in this paper we consider three years of experience incorporating the Trinity College Walk-on-Water Project in the senior design capstone experience. Educational objectives, project organization, learning activities and pedagogic outcomes in designing, building and operating both human-powered and robotic mechanisms for walking on a water surface are reviewed. Special attention is paid to assessment of the team learning process. Based on our findings over this period, we believe this project strongly improves student ability to combine knowledge from disparate areas of engineering science to accomplish a specific goal. At the same time, by combining an academically challenging goal with a hands-on approach supported by an aspect of fun and humor, motivation is enhanced as is ability to work within a dynamic team environment. We discuss the educational outcomes served by this project, and point out potential improvements that may enhance its applicability to a variety of programmatic approaches.

Introduction: The Trinity College Department of Engineering offers a two-semester, capstone senior design course intended to provide practical experience in engineering research and design, as well as in technical communication. Students enrolled in the course are expected to complete both an individual year-long project and a one-semester group project carried out in teams of 3-4. Since Trinity College has only a single engineering department, within which student interests range over mechanical, civil, electrical and biomedical engineering, the project topics selected for the individual project normally comprise a highly diverse set. Correspondingly, it is very important in our environment that the group project also maintain a strong cross-disciplinary focus. In addition, our intention is to provide the students with a group project that is academically demanding, but simultaneously also includes a significant component of fun and humor.

This paper describes an attempt to meet these criteria in the fall semesters of the 1999-2000, 2000-2001 and 2001-2002 academic years through the assignment of the design and fabrication of devices for walking on water[1, 2]. Students worked in multi-disciplinary teams, each of which was asked to fabricate and demonstrate a device for walking on water. At the end of the semester, a contest was held at the College pool to determine the fastest device in a timed trial of one length of the pool. During the first two years the project was carried out, the devices were required to be human powered. However, in the third year, as an experiment to assess the possibility of taking advantage of a strong interest in robotics within the department, the students were asked to design water-walking robots.

Educational Objectives: pedagogical objectives served by this project include

- Giving students practical experience with design problems ultimately requiring successful implementation within budgetary and time constraints
- Giving students familiarity with open-ended design problems for which multiple solution approaches are feasible
- Developing teamwork skills and team learning abilities
- Fostering the ability to combine knowledge from disparate areas of engineering science to accomplish specific goals.

Project Organization: on the first day of class, the instructor distributed directions for the project and divided the students into teams of 3-4. The students were grouped according to their field of interest so that each team received equal numbers of members with backgrounds in biomedical, electrical and mechanical engineering. To simulate a business approach, each group was given a formal sign-up sheet for the culminating contest, which the instructor explained was to be thought of as a binding contract. Each team was also given a set of rules for the project, along with a form for itemizing a proposed parts list with prices. A copy of the project rules is appended to this paper.

The teams were told that they had at their disposal a budget of $150 for design and construction expenses, but that no funds could be spent until the instructor had reviewed and approved their design drawings. Expenses beyond $150 were not approved. Over the three year period, approximately one third of the groups had their initial drawings rejected for exceeding the cost limit, generally necessitating extensive redesign. In fact, in retrospect the need to redesign to conform to budget guidelines was regarded as one of the most educationally valuable aspects of the project.

Although the class met once a week, no class time was spent on the project. Instead, each group was required to meet among itself on a weekly basis, and to keep recorded minutes of those meetings. All groups were then required to meet once every 3-4 weeks with the instructor to review progress in developing designs. The first of those meetings was a review of preliminary designs. Each group was expected to put forward at least two potential approaches at that time, in a preliminary form, and to present quantitative arguments for selecting one of those as their preferred method. This requirement was intended to motivate the students to consider multiple approaches, not just proceed with their first idea, and also to have the students analyze the relative merits of their ideas carefully and quantitatively. If the arguments presented were appropriate, the instructor approved the group to go forward to a full design. If not, another meeting was scheduled and the process was repeated.

At the second meeting, the groups were expected to present a final design proposal, with drawings and with an itemized parts list. The drawings were discussed, and if the total cost of parts was within the specified budget, the group was allowed to construct a prototype. It was then expected that the prototype would be fabricated and tested, so that at the third meeting, test results could be reviewed and revisions and redesigns discussed as necessary. Finally, the contest was held at the end of the semester.

Along with these technical criteria, the instructor has made an informal but strong attempt to encourage the students to incorporate an aspect of humor in their designs. This has generated a tradition of wit that has been a major motivating factor and substantially added to the students' enjoyment of the project. Examples can be seen in the photos below (note the mud flaps reading "BACK OFF!" and the associated shoes, which were named "New Improved Kinetic Expediters", or "N.I.K.E.s"). Other examples can be found on the project web page[2], as well as on a videotape that will be presented. As the project development was reviewed, a second conclusion that became apparent was that emphasizing the combination of levity with serious analysis and design helped motivate the teams to function as a cohesive unit. As a result, focus and commitment to the project increased significantly. This demonstrates a clear linkage between motivation, team unity and successful realization of the project goals.

Results and Discussion: all groups completed the project on time and within budget, as required. Of the human-powered devices, all but one group successfully completed one lap of the College pool (albeit, not always without mishap ….). Similarly, all but one of the robotic devices completed a lap.

The walk-on-water project is not technically out of reach; designing a device that can walk on water is well within the capability of undergraduate engineering students. What makes the project challenging are time and budgetary constraints. As such, a large part of the educational benefit of the project is derived from balancing the formulation of innovative potential solutions with the need to meet practical constraints related to actual construction. The mandate to construct and demonstrate a functioning device within time and cost limits emphasizes to the groups the importance of pursuing their designs in a spirit of creative critical evaluation. In addition, it fosters an appreciation for the necessity of repeated redesign until a satisfactory device is eventually achieved.

Developing Teamwork Skills: students worked in groups of 3-4. As has been pointed out by other authors[3], an important aspect of this type of project is that decisions that must be made for design to proceed (provision of buoyancy, thrust generation, *etc*.) are inherently interrelated. Hence, as the students weigh those decisions, a full team experience evolves, since no individual can make any single important design decision without affecting other decisions. Teams can, and certainly do, divide necessary computations and analyses among themselves. However, it is not possible for individual members to work entirely by themselves on specific project aspects, then simply combine results at the end. Only by working together carefully as a team throughout the design process can a successful outcome result.

We note specifically that exit interviews with our graduating seniors over the last three years have indicated that most of the students felt the inherent team experience of the walk-on-water project was one of the most valuable educational features of the department's curriculum.

Combining Knowledge from Several Areas: as with developing teamwork skills, design cannot proceed with analysis from one area of engineering alone, since analysis in one area affects decisions made in other areas (mechanism of thrust generation affects power provision, *etc*.). That characteristic of the project models the industrial design process realistically, since most large engineering projects include aspects of several areas of engineering science knowledge. In fact, walking on water as the topic of this project was selected specifically in part because it encompasses several areas of engineering. Again, students felt that bringing together training from many different subjects of the curriculum into one culminating project involving many of those subjects concurrently was one of the most valuable activities in our curriculum.

Summary and Conclusions: the Walk-on-Water project described here has proved to be a popular and effective mechanism for incorporating principles of teamwork and multi-disciplinary design in our curriculum. Student feedback on the project was very positive. When asked to evaluate the project quantitatively, 13/14 students judged the senior design course in general, and the walk-on-water project specifically, as the single activity of our curriculum from which they most learned to function on multi-disciplinary teams. 10/14 students ranked it as the activity from which they learned to design a system to meet specific needs. Specific student comments indicated their enjoyment of the project, and particularly their enjoyment of its humorous aspects.

Acknowledgements: We thank Ms. Danae Stoane and Professor David Ahlgren for their assistance with many aspects of staging and recording the project contest.

References

1. *mechanical engineering* **122(2)**, p. 14, February 2000.

2. Further information describing the contest may be found at the Trinity College Engineering Department web site, *www.trincoll.edu/depts/engr*.

3. K. Dahm and J. Newell, "Baseball Stadium Design: Teaching Engineering Economics and Technical Communication in a Multi-disciplinary Setting", *Proceedings of the 2001 American Society for Engineering Education Annual Conference and Exposition*, June 2001.

Robert Peattie

Robert Peattie is Associate Professor of Chemical Engineering at Oregon State University, although the work described in this paper was performed while he served as Assistant Professor at Trinity College. He received his Ph.D. degree in Chemical Engineering from Johns Hopkins University, then spent one year as Postdoctoral Fellow at Johns Hopkins. Prior to joining Trinity College, he spent several years on the faculty of Biomedical Engineering at Tulane University. His research concerns the physiologic response of cells and tissues to mechanical challenges.

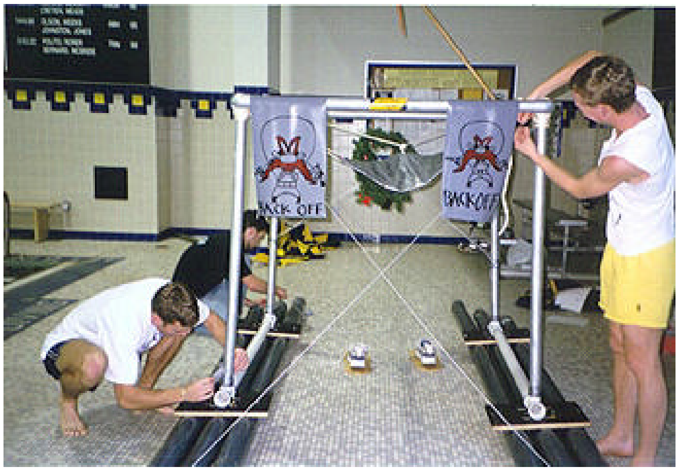
Andrew Robinson

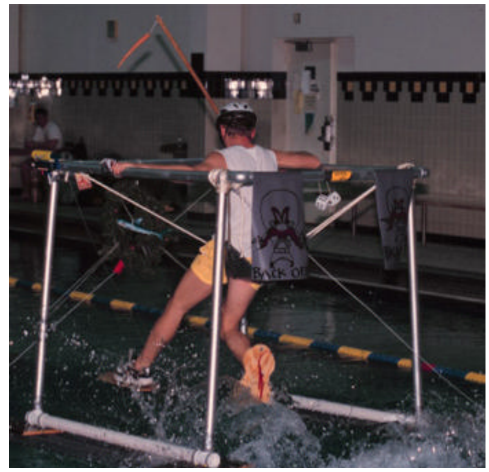
Andrew Robinson is a senior Engineering student at Trinity College. He anticipates receiving his B.S. degree in May 2002.

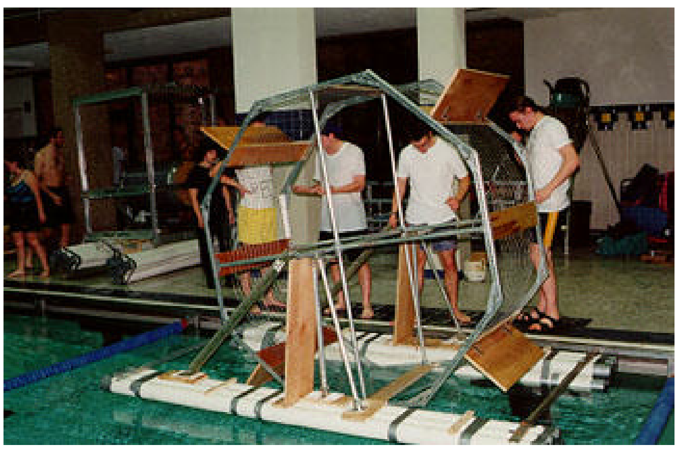
Andrew Malick

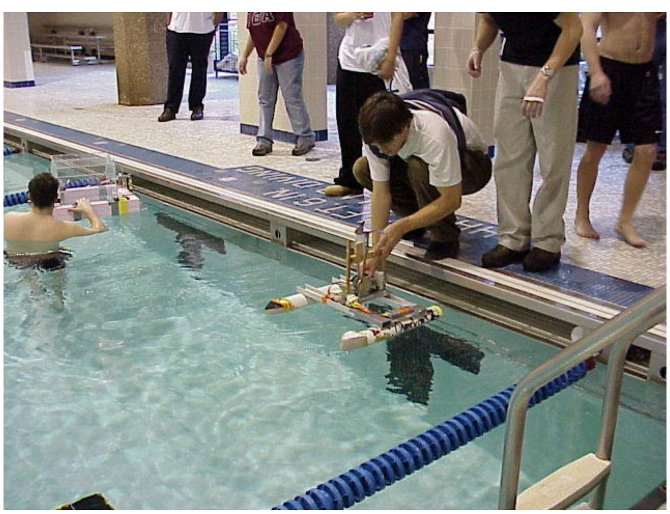
Andrew Malick received his B.A. degree in Engineering from Trinity College in May 2000. He presently works for Webcor Builders in San Francisco as a project engineer. He is pictured below running on water in his N.I.K.E.s.

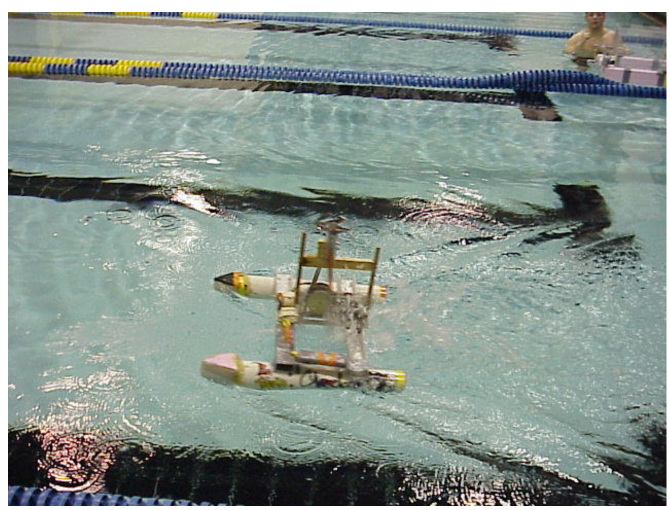
Teams and Devices from the Trinity College Walk-on-Water Contest, 1999 - 2001











2000 Trinity College Walk-On-Water Contest
Official Rules

The Trinity College Walk-On-Water Contest is a design competition for self-propelled, buoyant walking devices. Original and innovative device designs are encouraged. As such, minor modifications of items such as boats, kayaks, surfboards, *etc*. fail to meet the spirit of the contest and will not be accepted for entry. The following rules govern the contest.

1. The 2000 Contest will be held Sunday, December 10, 2000, at the Trinity College swimming pool, starting at 1:30 p.m.. Each group entering must submit an official entry form to Dr. Robert Peattie, Department of Engineering, Trinity College, by November 1, 2000. There will be a $25 entry fee per group entered that shall support the costs of lifeguard expenses.

2. Each entry must consist of a buoyant device operated by a single walker with a normal walking motion. The walker may supply power to the device only through his/her feet, and the device must be human-powered. External propulsion devices are prohibited.

3. Incorporation of recycled or recyclable materials in the device is strongly encouraged, although no restriction is placed on materials. Use of lubrication materials such as oils, greases, waxes or similar materials that could foul the pool water is not allowed.

4. Each entry must be designed by a student group, and each walker must be a student. Each group must designate a group leader, who must be a group member and shall be responsible for compliance with all contest rules. However, each group must also designate a faculty advisor, whose signature is required on the entry form.

5. Expenditures for each device are limited to $150.00 total. Estimated value of donated materials shall be included in the total. An itemized parts and materials list showing costs must be submitted by each entry the day of the contest. An official form is provided for this purpose, and must be signed by the faculty advisor. An entry not providing this list, or found by the judges to have omitted items from it, will not be allowed to participate in the contest.

6. The course shall consist of one length of the Trinity College pool (25 yards).

7. On the day of the contest, each entry shall be allowed 3 trials of the course. When an entry is called for its trial, it shall have 4 minutes to begin that trial. Entries not ready to begin in the 4 minute period shall forfeit that trial, but not any other trials. After all entries have completed their trials, fastest two will compete for overall championship.

8. The walker will be required to maintain vertical posture in the device. He/she may be supported by teammates prior to the start and after the finish, but may not be supported or touched in any way during the trial. Touching of the walker shall result in forfeiture of that trial, but not any other trials. Falling from the vertical position during the trial shall result in forfeiture of that trial, but not any other trials.

9. No supports or secondary assist devices (poles, ropes, rods, guide wires, *etc*.) may be used by the walker to maintain a normal stance.

10. The device may not touch or engage the walker in any way above the knees, except that the hands may contact any part of the device.

11. When the device is viewed from above in its normal walking configuration, no horizontal dimension may exceed 6'0". Viewed from the side, no vertical dimension may exceed 6'0". These dimensions apply to the device itself, not to the walker's position in the device.

12. The walker will enter the device at the pool edge. A support team may assist with entry and with transition to the officially sanctioned vertical posture. Once the walker is released, no further touching is permitted until completion of the trial.

13. Each trial shall commence with the back edge of the device in contact with one wall of the pool, and shall be complete when the opposite (front) edge of the device contacts the opposite wall of the pool, as determined by the judges.

14. Safety guidelines - each walker shall wear protective headgear while walking (*e.g*. bicycle helmet or equivalent). Each walker shall demonstrate to the satisfaction of the judges the ability to exit the device easily in the event of a fall prior to being allowed to begin trials. Lifeguards will be in the water at all times and will be available to assist fallen walkers.

15. Penalties for rule infractions are as follows:
    - 5 second penalty for every dollar over $150 limit.
    - 30 second penalty for every inch over 6'.
    - 120 second penalty for contact above the knees, other than with the hands.
    - Disqualification for violation of propulsion rule.
    - Disqualification for touching by teammates while walking.
    - Disqualification for violation of safety guidelines.

16. All decisions of judges are final. No appeals permitted.