AC 2008-236: STRATEGIES OF ASSESSING MULTI-DISCIPLINARY COLLABORATIVE EXPERIENCES

Samantha Richerson, Milwaukee School of Engineeirng

Samantha J. Richerson, PhD is the program director of the Biomedical Engineering program at the Milwaukee School of Engineering. She received her PhD from Louisiana Tech University in 2003 and taught for two years at Bucknell University. She moved to MSOE in 2005 and became Program Director in 2007. Her research interests are in effective teaching and learning methodologies as well as the effects of diabetes on balance and biomedical signal and image processing.

Deepti Suri, Milwaukee School of Engineering

Deepti Suri, PhD is the program director of the Software Engineering program at the Milwaukee School of Engineering. She received her PhD from University of Wisconsin Milwaukee in 2000 and has several years of industrial experience. She joined the SE faculty in 2000 and has been the program director of the SE program since 2006. Her research interests include software engineering architecture, analysis and design and educational research.

Strategies for Assessing Multi-Disciplinary Collaborative Experiences

Abstract

The Accreditation Board for Engineering and Technology (ABET) in its Criterion 3 requires that "engineering programs must demonstrate that their graduates have an ability to function on a multi-disciplinary team". Most schools are struggling to facilitate this interaction for their students and, although progress is slow, successful experiences are being developed. The next step is how to assess the effectiveness of this interaction and constantly improve it.

The Software Engineering (SE) and Biomedical Engineering (BE) program at the Milwaukee School of Engineering (MSOE) have developed a successful and sustainable interaction between their students in the junior year. This collaboration has been fine tuned over the past five years to clearly define the requirements and expectations of each student, and thus the instructors have turned their focus to assessing this interaction.

By using both direct measures (joint faculty assessments) and indirect measures (student self- and group assessment) faculty have begun to assess the effect of the interaction on the ability of students to function in multi-disciplinary teams. This paper will detail the multi-disciplinary experience, the assessment methodologies, as well as discuss how to adapt these methodologies to other multi-disciplinary collaborative experiences.

Introduction

The engineering graduates of the future must not only have a strong disciplinary base, but must also possess an ability think globally, to work on a team and collaborate with others in other fields, to appreciate specialists from across multiple disciplines and with multiple perspectives, and be demographically diverse[1]. The Engineering 2020 report[2] as well as a myriad of other sources lends guidance on how the engineering curriculum should be reshaped to meet the demands of the modern engineering revolution. In addition to these changes, the Council of Competitiveness also recommends that there be increased collaboration amongst engineers (inter-disciplinary activities) and others (cross-organizational activities) with relevant expertise[1,3].

Several of these recommendations have already been incorporated by the Accreditation Board for Engineering and Technology (ABET) for all engineering programs in its Engineering Criteria 2000 (EC2000). Its Criterion 3 known as ABET (a) thorough (k) describes the skills that the students are expected to know and accomplish at the time of graduation. Of particular interest and pertinent to the current discussion are criterions 3(d): an ability to function on multi-disciplinary teams, 3(f): an understanding of professional and ethical responsibility, and 3(g): an ability to communicate effectively.

In most engineering programs, capstone design courses tend to be the courses where these ABET criteria are typically addressed. Capstone courses have evolved over the years from professor defined designs to industry-sponsored projects where "real" problems are given[4,5]. As constructivist theories of learning became popular, and the academic community recognized that that learning is a social activity[6], these capstone project-based courses were seen as opportunities to improve students' ability to work in teams[7-9], and improve their communication skills[10-14].

However, it is challenging to accomplish all the tasks recommended by ABET during the capstone design projects. Several institutions (including MSOE) are finding ways to introduce this experience to the students much earlier in their career. This allows the capstone design experience to be the place where these skills are polished and re-assessed.

There have been several approaches tried by various engineering programs to incorporate the ABET mandated "experience in multi-disciplinary teams"[12,13]. Most common amongst them are (i) Assigning "tasks" to team members that tend to be outside their specialty and (ii) Creating teams in which students of two closely related majors are placed on a capstone design team for a short duration (typically a semester). These approaches are definitely steps in the right direction but have limitations.

This paper describes an innovative and sustainable framework to provide "multi-disciplinary" experience between the Biomedical Engineering (BE) and Software Engineering (SE) students at MSOE. The approach is neither an "after-thought", nor an "add-on" to one of the existing courses. It is a well-thought out plan for vertical and horizontal integration of this experience within the curriculum. This interaction not only provides curricular innovation but also rises to the challenge of providing globally relevant engineering education.

Project Context

The Milwaukee School of Engineering (MSOE), founded in 1903 is an educational institution based on an applications-oriented curriculum. From the beginning, leaders of business and industry cooperated in the institution's development, and a close relationship was established that has continued throughout the school's history.

The Biomedical Engineering Program at MSOE was started as a Biomedical Engineering Technology program in 1969. In the mid 1980's the program moved from a technology focus to an engineering focus, and was ABET accredited as one of the first four Biomedical Engineering programs in the country in 1990. MSOE's undergraduate Software Engineering program began operation in 1999 and produced its first graduates in May 2002. The SE program was accredited by ABET in September 2002 as one of the first accredited SE programs in the United States[15].

The curricula and more detailed information for the Biomedical Engineering program is available on the web site at http://www.msoe.edu/eecs/be. The curricula and more detailed information for the Software Engineering program is available at http://www.msoe.edu/eecs/se.

Multi-Disciplinary Collaborations between the Biomedical and Software Programs

The BE and SE programs at MSOE began to provide their students with multi-disciplinary experience in 2003, by fostering a relationship in their student's junior year outside of the capstone design experience. The SE students enrolled in a course on Requirements and Specification (SE-3821) work with the BE students who are in the third year of a four-year design project (freshman through senior years). The SE students collaborate with the BE student design teams to elicit, analyze, document, and specify requirements for their project[16,17]. This allows the BE students to scope their design project requirements while using SE students as consultants. SE students are also given a realistic exposure in the requirements gathering process on "real" project outside their domain.

Even though it appears the BE students are already three fourth's of their way through their projects, it is important to note that the BE students spend their freshman and sophomore years finding out more about a particular domain/area that they want to work in, doing basic research on the problem, investigating the applicable FDA regulations and completing a market analysis. It is in the junior year and the BE students are working on finalizing the scope of their project and defining their specifications; hence this collaboration is very timely.

The positive effects of this collaboration were immediately evident. The SE students started using the Volere process that they were being taught in class on the BE projects[18]. As part of the process, the SE students started asking questions, the answers to many of which the BE students had not yet discovered. It was evident to the students that several issues were being brought to light earlier in the project life cycle. Since then the collaborative experience has incrementally evolved and improved. Various faculty members from both programs have participated in the collaboration and "bought-into" the concept. A year after this collaborative experience, it was discovered that some BE student teams were requesting the SE students they worked with earlier to come and join their design teams in their senior year.

Evolution of Assessment in the Collaborative Experience

Prior to 2006, improvements to the collaborative experience were made based on the relevant comments that were gleaned from the course/instructor evaluation or from one-on-one conversations with the student teams. No direct or indirect assessment was undertaken because the focus of the improvements were on the collaboration and not on assessing the interaction for ABET.

Indirect Measures

By 2006, the course structure and content had been improved to the point where the focus of improvements turned to assessment. As a first attempt, a survey was given to both the SE and BE students in the 2006 experience to start an informal assessment on what they thought about the collaborative experience. To gather this initial baseline data, the BE and SE students were asked to answer questions (enumerated in Table 1) on a Lickert scale of "1" through "5" where "1" was an indication that they "Strongly Disagreed" with the statement, "3" was an indication that they were "Neutral" and "5" indicated that they "Strongly Agreed" with the statement. The questions that were asked and the average student scores are presented in Table 1.

As can be seen from the preliminary results SE students seemed to appreciate the experience (except for question#4) more than the BE students. The authors believe that the very early recognition amongst the SE students that they will be developing software for a different domain and the fact that the experience was driven out of the SE program may have influenced the results.

In 2007, the coordinators of this experience wanted to create an indirect survey measure that polled all the students regardless of major on the same questions. The questions developed focused on the ABET criterion 3(d) and (g). The students were given the survey at the midpoint in the quarter (Week 5) and then again at the end of the quarter (Week 10) to further garner data on the evolution of these skills throughout the quarter. A Lickert scale of "1" through "5" where "1" was an indication that they "Strongly Disagreed" with the statement, "3" was an indication that they were "Neutral" and "5" indicated that they "Strongly Agreed" with the statement was used. The questions that were asked and the average student scores in week 5 and week 10 of the quarter are presented in Table 2.

TABLE 1

SURVEY QUESTIONS ASKED TO THE BE AND SE STUDENTS TO EVALUATE THE COLLABORATIVE EXPERIENCE IN FALL 2006. AVERAGE STUDENT SCORES ARE REPORTED IN PARENTHESIS.

BE STUDENTS	SE STUDENTS
1. The collaborative experience with the SE students helped my team scope our design project appropriately. **(3.8)**	**1.** My knowledge about the requirements process has increased significantly after this course. **(4.3)**
2. The collaborative experience with the SE students helped my team think out questions that we had not originally thought about. **(4)**	**2.** During this collaborative experience, I had a chance to apply the requirements process to a realistic project. **(4.2)**
3. The work products produced by the SE students will help my team do a better "design" next quarter. **(3.5)**	**3.** During this collaborative experience, I became familiar with a different domain. **(3.6)**
4. During this collaborative experience, I learned how to talk to engineers who are experts in a different domain. **(3.8)**	**4.** During this collaborative experience, I learned how to talk to engineering who are experts in a different domain. **(3.2)**
5. The collaborative multidisciplinary experience with the SE students was beneficial to me. **(3.6)**	5. The collaborative multidisciplinary experience with the BE students was beneficial to me. **(3.7)**

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TABLE 2

Survey questions asked to the BE and SE students to evaluate the collaborative experience in fall 2007. Average student scores are reported in after the middle and the end of the quarter.

QUESTIONS	Average Score After Week 5	Average Score After Week 10
1. BE and SE students have integrated well as a team.	3.4	4.1
2. The entire team has worked well together so far.	3.6	4.1
3. We, as a team, have successfully moved the project forward	3.6	4.1
4. I feel more comfortable in talking to engineers from a different domain today than I did at the beginning of the quarter.	3.2	4.0
5. This interdisciplinary experience is beneficial to me.	3.8	4.3
6. I know more about the requirements process today than I did before the start of the quarter.	4.1	4.4

As can be seen from the Table 2, the results improved significantly between the midpoint (Week 5) and end of quarter (Week 10). The midpoint assessment results provided the instructors with some information on the issues that the teams were struggling with and allowed the instructors to intervene. The intervention involved not only talking to the individual teams but having a lecture session and discussion on "Effective Communication." In subsequent offerings, we would like this lecture earlier in the quarter so that the teams are armed with the some skills required to work on large teams.

The authors also found a positive correlation between the scores on the survey and the ability of the team to work together. Teams that were struggling within their groups to communicate effectively had scored lower on the week 5 survey, especially for questions 1, 2, 4, and 5. This is to be expected as teams that are not able to communicate do have trouble integrating well into a team, and working together. After the "Effective Communication" lecture, the student groups that were struggling to communicate, did start to communicate better, but still had lower score on the Week 10 survey than other teams.

Overall, the results of the survey provide the instructors not only with an indirect measure for 3(d) and 3(f) but also a way to measure student perception about the interaction and see if student perception improved from year to year.

Direct Measures

As indirect measures of ABET criterion are not sufficient to prove that students have attained the skills set forth, the instructors knew that several direct measures would have to be incorporated in the assessment process. Though there can be several approaches that can be used for direct assessment, the authors believe that if the experience is effective then

(i) The end product that is produced will be of much higher quality.
(ii) The integrated team will have a common understanding of the problem being solved, the domain and the processes that will be used to solve the problem.

It is for this reason that two different direct measures were integrated into the course in the form of rubrics. The first rubric was used to assess the final reports submitted by the teams that detailed the requirements process and the final specifications developed by the team. A copy of that rubric is attached as Appendix 1. A well prepared final requirement specification report was an indication of a thorough understanding of not only the problem that the team originally set out to explore but also a good understanding of the context in which the product will be operated (i.e. its use cases), its assumptions, risks and constraints along with the functional and non-functional requirements. It would not come as a surprise to the reader that the teams that had a good final report were the teams that had worked well together and had attacked the problem from all angles.

The groups were also required to give a group presentation at the end of the quarter that detailed their group's progress through the requirements process. The instructors developed the rubric to assess both content as well as delivery of the material. Special care was taken to ensure that the requirements for the presentation included topics from both the BE as well as the SE domain and emphasized group collaboration and rapport. Each item was measured on a 5 point scale (1 being not present, 3 being average, and 5 being excellent) by both instructors during the presentation. Grades for the presentation were then given as an average of these two rubric grades. The rubric can be seen in Appendix 2.

Results of the presentations were mixed. It was clear to the instructors which teams had met ABET Criterion 3 (d) and (g) because of the rapport seen between presenters during the presentations. Groups that functioned well together, had the ability to communicate effectively, and were able to work in multi-disciplinary team, not only could present their mutual work more effectively, but their requirements for their project were more in-depth, thought-out, and generally at a much higher level than those teams that failed to work together effectively as a team. Additionally, those teams that had functioned well in the multi-disciplinary environment were able to answer questions outside of their initial domain (i.e. SE students answering physiology questions, and BE students using SE terminology to explain flow processes).

Adapting these Methodologies to other Collaborative Experiences

Through years of revision of this process, the authors have the following advice for individuals interested in creating collaborative experiences.

Timing: Ensure that the teams you are working with are both in the correct place in their curriculum to start this process. For SE students in this situation, this meant that the course was the first time they were exposed to the requirements process as well as the application domain. In order for this to occur, students have to be mature enough to understand that working through the process in another application domain will be of use to them. For the BE students in this case, they had to have an initial project idea as well as some background research on what the product was supposed to do. It is unwise to talk to design students about writing requirements without an application for them to directly relate to.

Equity: Fairness in the amount of time and course credit given to the students to complete this project is necessary. Students generally see it as unfair if the hours required (as well as credits) by group members of different majors are not the same.

Communication: In general, teams will function much better if there is at least one hour per week scheduled in common for the two courses. This is one hour in which the team members from both programs are guaranteed availability and the instructors are also available for questions. This process often finds that students also need to meet outside of class to complete coursework, and with the increase in group projects this can sometimes be difficult. Any common time that can be scheduled between majors aids in the collaboration and forming of the group. It is our recommendation that the group members do not rely solely on technology for communication (e.g., e-mail, Instant Message, or other electronic media). It is our experience this does not foster clear communication and generally leads to more problems than it solves. Groups that meet face to face in an environment free from distractions are those teams that tend to work better and accomplish more in a given time period.

Integrated Teams: In initial offerings of this collaboration, BE instructors gave feedback to the BE student teams whereas the SE instructors gave feedback to SE students. The fact that the instructors of both the courses did not meet the integrated teams one-on-one demonstrates a lack of commitment by the instructors to the students. In the most recent offering (Fall 2007-08), the same assignments were submitted by both the teams and both were graded on exactly the same deliverables by both faculty members. This takes a lot of coordination between faculty teaching the collaborative experience, but benefits the students and the experience greatly. By having the instructors giving feedback as a team to the collaborative team, students gained a view of a multi-disciplinary team (the professors), and how they interacted with one another. Additionally, there were not any confusing requirements (one professor requiring one thing, and another professor requiring something else) and students were focused on one goal throughout the entire process.

Assessment: Start small. One survey given to the students allows them to give you feedback on the process and items they feel are "unfair" and "different" between the two professors. Put questions on your survey that directly ties to ABET outcomes. Although this is an indirect measure, it is the first step in the process. After refining the experience enough to obtain consistent results from the process, you can move to more direct measures. Again, write the questions/topics that you want to directly measure and design the assignments in the course so that these measurements can be taken. Create a rubric and then apply it to your assignments. Of course, to close the loop, analyze the results and improve the process used to help your students meet the outcomes.

The authors believe that this experience is set up in such a way that it can be very easily extended to any engineering discipline, or even further, to any other non-engineering disciplines that engineers often work with.

Conclusions

The authors believe that effective multi-disciplinary experience can be provided as part of every engineering curriculum. If the engineering programs buy into the concept and commit themselves to providing this experience to their graduates, then various opportunities exist for collaborative experiences within each institution.

The authors have been working on an innovative collaborative experience between the Biomedical and Software Engineering programs at their institution. This experience has been refined as the years have gone by and can be used as a template to start multi-disciplinary collaborative experiences at various other institutions.

There are some limitations to this methodology. Students only begin their interaction with those of another discipline. It is up to the individual students if they wish to join the BE design teams for the remainder of the project (1.5 years). A more sustained interaction is being developed by the two programs to further increase the multi-disciplinary teamwork.

References

1. National Innovation Initiative, "Innovation Skills Working Group Final Report," *Council on Competitiveness*, 2005.The report is also electronically available at http://www.compete.org/docs/pdf/NII_21st_Century_Innovation%20Report.pdf
2. National Academy of Engineering, "The Engineer of 2020: Visions of Engineering in the New Century," *The National Academies Press*, 2004.
3. Smerdon, E.T., "Lifelong Learning for Engineers: Riding the Whirlwind", *National Academy of Engineering: The Bridge,* 26, Spring/Summer 1996.
4. Dutson, A.J., Todd, R.H., Magleby, S.P., and Sorensen, C.D., "A Review of Literature on Teaching Design Through Project-Oriented Capstone Courses," *Journal of Engineering Education*, Vol. 76, No. 1, pp. 17–28, 1997.
5. Sheppard, S.D., "A Description of Engineering: An Essential Backdrop for Interpreting Engineering Education," *Proceedings Mudd Design Workshop IV*, Harvey Mudd College, Claremont, CA, 2003.
6. Minneman, S., *The Social Construction of a Technical Reality*, Doctoral Dissertation, Stanford, California: Stanford University, 1991.
7. Dym, C.L., Wesner, J.W., and Winner, L., "Social Dimensions of Engineering Design: Observations from Mudd Design Workshop III," *Journal of Engineering Education*, Vol. 92, No. 1, pp. 105–107, 2003.
8. Mikic, B., and Grasso, D., "Socially-Relevant Design: The TOYtech Project at Smith College," *Journal of Engineering Education*, Vol. 91, No. 3, pp. 319–326, 2002.
9. Pimmel, R., "Cooperative Learning Instructional Activities in a Capstone Design Course," *Journal of Engineering Education*, Vol. 90, No. 3, pp. 413–421, 2001.
10. Quinn, R.G., "The Fundamentals of Engineering: The Art of Engineering," *Journal of Engineering Education*, Vol. 83, No. 2, pp. 120–123, 1994.
11. Rittel, H.W.J., and Webber, M.M., "Dilemmas in a General Theory of Planning," *Policy Sciences*, Vol. 4, pp. 155–169, 1973.
12. Todd, R.H., Magleby, S.P., Sorensen, D.D., Swan, B.R., and Anthony, D.K., "A Survey of Capstone Engineering Courses in North America," *Journal of Engineering Education*, Vol. 84, No. 2, pp. 165–174, 1995.
13. Tooley, M.S., and Kevin, D., "Using a Capstone Design Course to Facilitate ABET 2000 Program Outcomes," *Proceedings, ASEE Conference & Exhibition*, Session 1625, 1999.
14. Ulrich, K.T., and Eppinger, S.D., *Product Design and Development*, 3rd ed., McGraw-Hill, 2003.
15. "ABET Accredited Engineering Programs," http://www.abet.org/schoolareaeac.asp.
16. Suri, D., Gassert, J., "Gathering Project Requirements: A Collaborative and Interdisciplinary Experience," *ASEE Annual Conference and Exposition*, CD-ROM, Portland, Oregon, 2005.

17. Suri, D., Durant, E., "Teaching Requirements through Interdisciplinary Projects", *2004 ASEE North Midwest Regional Conference*, CD-ROM, Milwaukee, Wisconsin, 2004.
18. Robertson, S., Robertson, J., *Mastering the Requirements Process*, Addison-Wesley, 1999.

APPENDIX 1: Rubric created by instructors to directly measure the final report given by each multi-disciplinary team.

	Beginning - 1	Developing - 2	Accomplished - 3	Exemplary - 4
Goals	Goals do not provide a rational product basis; list of stakeholders is superficial or incomplete	Goals are incomplete or unclear; stakeholders are superficially addressed	Goals are mostly complete, but the benefits and terminology are not always clear; stakeholders need to be defined in more detail	Goals are clearly articulated with documented advantages and measurement criteria; unambiguous terminology; comprehensive list of users and stakeholders
Context Diagram / Business Events	Data flows are missing or so limited as to be unusable for UC generation; adjacent systems are missing or not sufficiently described	Key adjacent systems are missing, or most adjacent systems are ill defined	The diagram is mostly complete, but categorization is missing or key interactions or events are missing	Diagram is clearly documented and adjacent systems are clearly and logically categorized into the 3 types; appropriate modeling techniques are used (*e.g.*, state diagram, ER diagram, mind maps); supporting materials referenced
Glossary	Many terms are missing or there are numerous ambiguous usages	Most key terms are defined, but not in sufficient depth of be useful to the domain novice	The glossary is sufficient that a person working in the domain a short time would understand the document, but some terminology is overly redundant or ambiguous	As SRS is being read, all relevant terms were found in the glossary. Consistent terminology used throughout
Constraints , Assumptions and Risks	Missing	Stated but not justified. Relevant risks are raised but not presented in detail.	Reasonable items listed with basic support that leaves the reader with a list of questions that need to be answered	Areas are addressed and clearly documented support material is provided as appropriate. Proper monitoring and tracking of risks is shown.

Use Cases	Do not reflect primary business events and are not readily derivable from the work context diagram	Use cases are appropriate in scope, but superficial in detail, not providing enough information for design. Or, the UCs specify significant design constraints that are unjustified.	The purpose of the UC case is clear and there is sufficient detail to write good requirements, but some key items are missing from the template. UCs are appropriately chosen and cover most major functionality. Unjustified design constraints are kept to a minimum.	***All*** sections are appropriately completed: description, actors, preconditions, basic flow, alternative flows, exception flows, etc. The UCs are sufficiently wide reaching to encompass the project goals. Any assumptions, constraints and risks specific to the UCs are documented.
Requirements	Severely incomplete in detail and coverage. Several non-functional categories are unaddressed.	Sufficient coverage, but ambiguous or missing many relevant items (*e.g.*, Fit Criteria) for several requirements.	Provide a sound basis for design, but are mostly lacking in traceability. Ambiguity is present, but is the exception and not the rule.	Traceable to UCs and business goals. They cover all functionality described in the use cases. They are complete and unambiguous.

APPENDIX 2: Rubric created by instructors to directly measure the final presentation given by each multi-disciplinary team.

Presentation Rubric:

Context of Presentation
Introduction to the product

- Should include an introduction to the product as well as the team members

Goals of the product

- Should only include goals, not metrics

Context Diagram of the product

- The flow should be explained in a linear manner

At least one use case for the product

- Must include the functional and non-functional requirements that were derived from that particular use case

Strengths and Weaknesses of the collaborative experience

- Things you learned from the experience (good, bad and ugly)

Conclusions

- This may include work that needs to be completed subsequent to this interaction

Delivery of Presentation

Group Balance and Rapport

- Group member's participation is well balanced
- Members are in-sync with each other

Comfort, Delivery and Articulation

- No fidgeting or nervous mannerisms, members are confident and articulate

Audience Awareness

- Members have eye contact and audience is involved (at least mentally) in presentation

Information Quality

- Use of visually attractive charts and diagrams. Space on slides was used well and information

  was accurate and in-depth as to enhance the presentation

Had ability to answer questions professionally

Good use of time allotted for presentation