The Design of a Robust Tool for the Measurement of Understanding the Impact of Engineering Solutions

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introduction

The modern world is changing at a rapid pace and the nature of engineering problems is evolving alongside it. It is not sufficient to consider engineering solutions only in terms of the formulas to be applied. Rather, factors such as environmental issues, cultural practices, and political situations must be considered in order to develop appropriate engineering responses to global problems. As such, engineering students must be conscious of the global environment and able to develop creative, viable, appropriate engineering solutions for the ever-changing modern world. This objective follows a national trend in engineering education to prepare students to handle new global challenges and to combat declining interest in the field of engineering. This idea is reinforced in an article entitled "The Research Agenda for the New Discipline of Engineering Education" in the October 2006 issue of the *Journal of Engineering Education.* As a means for achieving this objective, this research focuses on the development of an appropriate teaching technique and assessment method for ABET outcome "h," "that students attain the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context."

background

Before developing and implementing any kind of teaching technique and assessment method, a foundation in learning, assessment, and quality improvement theory must be established. Bloom's Revised Taxonomy is based in educational psychology and presents a classification of learning skills and objectives for students. The goal is to present a holistic approach to learning by combining the three educational domains—affective, psychomotor, and cognitive. The cognitive domain, where traditional educational methods fall, is best illustrated by a pyramid, as seen in Figure 1. In order to reach the apex, the ability to create, students must first master the lower levels of the pyramid in sequence. Following the steps of the pyramid represents the process of thinking things through. The Four Pillars of Knowledge represent the progression of learning—factual, conceptual, procedural, and metacognitive. The metacognitive pillar is the most advanced of the four and can be defined as "learning to learn." This means that a student is aware of his own personal learning skills, habits, and performance. Assessment can be represented by a feedback loop, as seen in Figure 2. In terms of educational assessment, the instructor provides course content to the student, who then uses the given teaching technique and a learning process to produce an output, such as an exam or homework assignment, demonstrating deeper understanding of the course content. This output is then assessed by the instructor who then communicates this assessment back to the student and modifies the course content as appropriate. Then, the cycle repeats. With each iteration of the loop, the student should add to previous knowledge and continue to grow in understanding. This assessment model relates to the concept of continuous quality improvement, a results-oriented program of process improvement based in the scientific method. The general steps of a continuous quality improvement program are shown in Figure 3. Continuous quality improvement can be used to close the assessment loop discussed previously and can be considered from two vantage points. Faculty can use continuous quality improvement ideas in teaching course content and in assessment methods, while students can use continuous quality improvement ideas in developing and demonstrating deeper understanding.

search criteria and constraints

Appropriate search criteria and constraints had to be determined before any ideas as to teaching techniques and assessment methods could be developed. Perhaps the most important criterion was that the proposed ideas must reach all engineering students. Additionally, the selected methods must fit within current curriculum and program requirements, meaning that new courses could not be added. The chosen teaching technique had to utilize a semester-long evaluation format. It is easier to observe a student's growth of understanding continuously over the course of a semester, making the semester-long evaluation format preferable to the "snapshot in time" format of a single embedded question. The teaching technique to be selected also needed a quantifiable, accurate, and consistent assessment method. Both elements of the design, the teaching technique and assessment method, had to be flexible enough for adaptation to various classes, both technical and non-technical. Finally, the proposed ideas had to be a valid measure of the criteria, have face validity, be appropriately challenging, and maintain student interest. Based on these criteria and its connection to the desired outcome of understanding the impact of engineering solutions in a global, societal, economic, and environmental context, Engineering 149: Technology and Society, appeared to be the logical choice for implementing the design in Hofstra University's Department of Engineering.

Hofstra University engineering 149: technology and society

According to the Hofstra Course Description, "the interrelationship between technology and society in the past and present is established" in this course, (Hofstra Course Bulletin). The desired ABET outcome directly relates to this. Additionally, the course is a part of all engineering program requirements and, therefore, it reaches all students. Currently in Engineering 149, each student chooses one technological innovation to trace through history. Students are required to prepare three written reports and two oral presentations. From my personal experience as a student in this class, I felt that this was an interesting approach and looked to modify it in my design.

literature review

A literature review was conducted in order to gain ideas about methods currently in use for promoting global awareness within engineering curricula and in developing and using assessment methods. "The Research Agenda for the New Discipline of Engineering," from the latest issue of the *Journal of Engineering Education* (1), reinforced the research objective and identified key educational areas in need of change. "Closing the Loop: The Difference between Making Improvements and Continuous Improvement,"(2) from the 2001 ASEE Conference, discussed the importance of implementing continuous quality improvement programs in order to keep pace with the changing criteria determined by ABET. "The Development of a Global World View,"(3) from the 2006 ASEE Conference, explained the approach of Baylor University's School of Engineering and Computer Science in achieving the desired outcome of increased global awareness. "The Parallel Curriculum Model: Understanding Engineering Educational Innovations to Optimize Student Learning,"(4) also from the 2006 ASEE Conference, discussed the need for an organized curriculum in order to optimize the overall engineering educational experience. "Learning Journals as a Cornerstone for Effective Experiential Learning in Undergraduate Engineering Design Courses,"(5) again from the 2006 ASEE Conference, presented the teaching technique of learning journals as a means for students to actively engage in reflection on course topics to stimulate growth of understanding and explained the role of learning journals in a continuous feedback cycle. "Rubric Development and Inter-Rater Reliability Issues in Assessing Learning Outcomes,"(6) from the 2002 ASEE Conference, focused on using rubrics to assess student work and addressed the issue of consistency in assessment. Using these ideas along with the determined criteria and constraints, I selected an appropriate teaching technique and assessment method for the desire outcome.

learning journals and application to engineering 149

The teaching technique I selected is learning journals, where students write weekly journal entries (100-300 words per entry) discussing pertinent class topics and relating them to explicitly stated course themes. If desired, the instructor can provide leading questions or specific issues to be addressed in relation to the overall weekly topic. The project will culminate in a significantly longer entry (minimum 1000 words) tying weekly topics together by highlighting the common threads—the stated course themes—and using reason to make conclusions. Students will be assessed on not only their comprehension of the topics, but also how well they can identify relationships and address the larger umbrella issues for the course. Each week, the bigger picture should become clearer and students should show increased understanding and greater ability to unite the themes and topics as the semester progresses. Additionally, much of the credit given for the final paper will depend upon how effectively and logically the student makes conclusions about the issues. Entries are to be done weekly and submitted for grading monthly (schedule to be determined by instructor). Each entry is given a grade based on the specified assessment method. The final entry will be weighted more heavily than previous individual entries and will be assessed using the same method.

To apply this idea to Engineering 149, the course themes must be clearly defined. They are the historic and present interrelationship between engineering solutions and society; the impact of engineering solutions in a global, economic, environmental, and societal context; the desired and unforeseen consequences of engineering solutions; and the cultural worldviews toward engineering solutions. These themes must also be made known to the students. Each student will select one innovation and trace its creation, development, adaptation, usage, and broader societal and cultural impact throughout history and society. Each week, students will focus on another significant time period or culture as determined in class and discuss their chosen subject in context. As the semester progresses, students should make connections between the various cultures and time periods examined to draw a timeline for this specific subject. The final entry must address the present state of this subject and also discuss possible future adaptations, uses, and consequences (arguments can be based on hypotheses and theory, but must use sound logic and reason). Additionally, the final entry requires that students highlight what, if any, commonalities exist for this subject throughout history and society and why these commonalities exist or do not exist, in addition to other related issues (major design flaws, differing value in various cultures, use/disuse related to lack of resources, etc.). Also, the student must use reason to make conclusions about the overall historical and societal significance of this subject.

As previously stated, the instructor can provide students with leading questions. Using the topic that I focused on as a student in Engineering 149, financial systems, as a sample, the following are examples of leading questions and possible student responses:

- Question: Discuss the materials used. How do they relate to the physical environment of the culture/time?
    - Response: In ancient China, coastal settlements used shells, while inland agricultural societies used cattle for bartering.
- Question: Discuss the economic value of the subject and the related power structures.
    - Response: After the collapse of the Roman Empire, minting rights shifted from the government to wealthy individuals and religious groups. Money was stockpiled and those who held it also held political, social, and economic power.
- Question: Talk about the subject in terms of cultural diffusion.
    - Response: Medieval Christian Europe was reluctant to use paper money because it was milled in Spain by the Moors, who were viewed as “heathens.” However, convenience triumphed and the use of paper money became widespread.

These same leading questions can be used to get students to think about the environmental, economic, and global implications of a variety of technological innovations.

rubric assessment and application to engineering 149

The chosen assessment method for the learning journals is a rubric. The professor/rater can use the rubric framework to differentiate student performance. With practice, this type of assessment method has been shown to be a reliable measurement tool.

The assessment of the learning journals is based on a student's comprehension of the topics and ability to identify relationships and address course themes. Rubrics provide a clear, standardized grading framework that is explained to students to ensure that expectations are understood. In application to Engineering 149, the rubric would utilize a Likert scale from 1 (Unsatisfactory) to 5 (Excellent), although a three point scale could also be used. Six aspects would be measured in each entry:

A. understanding of the subject matter
B. how well issues are addressed and understood
C. appropriate placement of the subject in historical/cultural context
D. how well connections are supported
E. how well given questions are answered
F. how thorough the discussion is and how logical the arguments are

The following is the full rubric with which to assess each learning journal entry in Engineering 149:

5: Excellent
- Student shows excellent fundamental understanding of the subject matter
- Student addresses all issues clearly and logically and displays a real understanding of the issues
- Student appropriately and correctly places subject matter in the context of history and society
- Student uses excellent support in making logical connections between time periods/cultures
- Student answers given questions well
- Student is thorough in their discussion and presents a clear, logical argument

4: Above Average
- Student shows a solid understanding of the subject matter
- Student addresses all issues with a high degree of clarity and logic and displays a good understanding of the issues
- Student appropriately and correctly places subject matter in the context of history and society
- Student uses good support in making logical connections between time periods/cultures
- Student answers given questions fairly well
- Student is reasonably thorough in their discussion and presents a fairly clear, logical argument

3: Satisfactory
- Student shows an average understanding of the subject matter
- Student addresses some issues clearly and logically and displays an average understanding of some issues, although does not address all issues

- Student attempts to place to place subject matter in the context of history, but does not necessarily do so correctly or appropriately
- Student has somewhat faulty support and does not always make logical connections between time periods/cultures
- Student is only somewhat thorough in their discussion and their arguments are not always clear and logical

2: Below Average
- Student shows a very limited or flawed understanding of the subject matter
- Student fails to address many issues and/or incorrectly addresses and understands issues
- Student is unable to correctly place the subject matter in the context of history and society
- Student has very limited or flawed support and is unable to make logical connections between time periods/cultures
- Student is very elementary in their discussion and presents no real argument or explanation

1: Unsatisfactory
- Student shows no real fundamental understanding of the subject matter
- Student does not address any of the issues/shows no understanding of the issues
- Student cannot place the subject matter in the context of history and society
- Student makes no logical connections between time periods/cultures
- Student does not answer given questions
- Student does not present any kind of clear, logical argument or explanation

analysis of strengths and weaknesses

Certain strengths and weaknesses are apparent in this design. One strength is that the assessment criteria are clearly outlined for all students. Ideally, every student will strive to achieve scores of excellent on the journal entries. Additionally, the learning journals require that students analyze, evaluate, and make connections to reinforce the concepts of the desired outcome. Additionally, diverse student backgrounds are utilized. Students can be encouraged to use personal experience, work experience, and outside interests in writing entries. Additionally, the desired outcome can be judged mid-semester and adjustments can be made as needed. The primary weakness is that grading can be difficult and time consuming. The entries are of considerable length and there are several aspects to measure in assessing each entry. Large class sizes will exacerbate the time issue. However, engineering programs that employ teaching assistants may be able to overcome time issues. Also, the learning journals are highly dependent on a student's analytical writing skill.

alternative course applications

Learning journals can be applied to a variety of classes, both technical and non-technical. They can be effectively employed in freshmen seminars to give new students the opportunity to explore the influences of engineering in daily life. Leading questions can be used to help students examine different engineering fields to broaden their knowledge beyond their chosen specializations. A course in engineering economics may also be a good fit for the implementation of learning journals. Students can use the entries to discuss the interplay of engineering and business in the corporate world—taxation, funding, material and equipment costs, and return on investment are some of the topics that can be addressed, perhaps in relation to current events or case studies. Learning journals can also be used in project management classes. Entries can focus on why implementation of an engineering solution was successful or unsuccessful, how problems were rectified, and the impact of the solution after its

completion. Additionally, learning journals can be used in design courses. Students can discuss the implications of the materials being used, how much the product will cost to design, and who the users will be, while examining related projects. Special topics courses can also use learning journals in a similar manner.

conclusion

Learning journals are being implemented this semester at Hofstra University in Engineering 149: Technology and Society. At the end of the semester, their use will be evaluated and adjustments made as needed. In particular, student expectations, the extent of the rubric including the measurement areas and scale, and the topics being covered will be examined to determine whether the loop is effectively being closed. Commitment to and experience with using learning journals should increase their effectiveness.

In order to succeed in the modern world, engineers must be conscious of the world around them. This need for global awareness is reflected in ABET outcome "h," "that…students attain the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context." Learning journals and rubric assessment provide one way to help students develop and demonstrate deeper understanding of course content in relation to this desired outcome.

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