Extended Abstract - Make Learning More Real: An Introduction to Reflective Learning in a First-Year Engineering Design Course

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Abstract - **Reflective learning methods have been practiced in many college-level liberal arts courses in the liberal arts and have begun to appear more often in engineering curricula. Fundamentally, the term "reflective learning" refers to the active monitoring and evaluation of one's own learning in order to discern concepts, patterns and relationships. This leads to recognition of what was taught and how new information can be added to an existing body of knowledge for application to college coursework, life outside the classroom, or even the engineering workplace. We were aware of the use of reflective learning in a multi-disciplinary and multi-age engineering project-based course at other institutions, and wondered if this technique would enhance the learning of fundamental engineering skills for our first year students. To that end, a simplified weekly reflective journal assignment was added to our students' workload in order to observe and measure their capability to identify, qualify and implement new skills and insights. Students recorded one or more skills and reflections for each week of the semester to answer these questions: *What did you learn? Why is it important? Where else could you use this skill?* Entries were graded periodically and, collectively, these grades comprised 10% of the students' overall course grade. While most students identified specific skills and observations pertaining to the course, occasionally their responses containing skills learned in other courses or in out-of-classroom situations on and off campus. There was no length requirement, and some students were more expressive than others. As expected, certain students completed the assignments more diligently than others, resulting in descriptions containing a greater sense of perception and synthesis of related ideas. Since it was also our intent to guide students into identifying similarities in content and application between our course and other required "core curriculum" courses, as well as application to everyday life, we were encouraged by responses involving ways in which specific technical skills taught in our course could be used to save time and improve accuracy in other courses. The students gave examples such as physics or chemistry lab reports, organizing information for assignments in an evidence-based humanities course, and noting the similarities between estimating the cost for a completed conceptual design and estimating the cost to pursue a hobby. By adopting a basic, easy-to-use format for our reflective journals, we were able to "make learning more real" by enabling our students to identify not only what they learned, but what it meant to them.**

Index Terms – Reflective learning, intellectual development, first-year design.

INTRODUCTION

Engineering students invest a great deal of time and energy to discover, master and (hopefully) retain the technically demanding skills that enable them to solve the world's problems – but what does all of this learning really mean to them? Many first year students have a limited understanding of the skills that need to be mastered before entering their professional careers. They are often surprised to learn that our introductory engineering design course is communications-intensive (occasionally a student will ask, "So when do we get to do real engineering?"). Reflective learning methods helps students to realize that "real engineering" is more than graphs and equations, and involves the sharing of ideas. The reflective journal has been, and will continue to be, a useful tool that helps students to discover the relevance of their education, as well as to promote the type of intellectual development necessary to become effective engineers.

PROJECT BACKGROUND AND PURPOSE

Our one-semester, first year design course is taken by nearly 800 students. The typical class size is 50 students with two instructors per class. These classes may also contain small numbers of second- or third-year students, who were not able to take the course during their first year. The course learning outcomes include the ability to exercise creative and critical thinking skills to solve open-ended engineering problems through collaboration on a team, an ability to select an optimal solution, and an ability to effectively communicate the design solution and its intermediate stages: graphically, orally and in writing [1]. Reflective learning relates to the development of creative and critical thinking skills, by revealing possibilities that are not immediately

evident, but often turn out to be the most useful, as well as creative and/or innovative.

We decided to conduct this assignment after we learned of its potential usefulness through Purdue University's summer 2013 Engineering Partners in Community Service (Purdue EPICS) short course [2]. In the Purdue EPICS reflective journal assignment, students were required to identify what they learned, how they learned it, and what it meant to their education on an ongoing basis.

Another major motivator for students to learn and use any skill or insight is their own perception of its relevance. The work of Turns and colleagues asserts that it is necessary to employ reflection to discover the "deep lessons" of engineering design, implying that it would provide relevance. [3] Similarly, Palmer, et. al. identified the role of reflection as providing "new understandings" that students would add to their own accumulated knowledge and experience, thereby providing relevance. [4]

To benefit from reflection, students need to refine their learning skills by realizing that not all knowledge is absolute; much of it is uncertain and depends on context. [5]-[6]. Therefore, it is up to each student to decide what they will accept as true, and under what conditions. Felder and Brent [6], [4] identified four stages of intellectual development, from absolute knowing, i.e., everything is certain, to contextual knowing, i.e., each person takes responsibility for making judgments about what is right. The four stages can be summarized as follows [5]-[6]:

- **Absolute knowing**: All knowledge is certain, and authorities have the one right answer to any question that matters. Students do not question the validity of the information "fed" to them.
- **Transitional knowing**: Some knowledge is certain, and some is uncertain. Authorities indicate which is which, and students make judgments about uncertainties, relying on prescribed procedures or intuition rather than on evidence; biases are likely to influence judgments.
- **Independent knowing**: Uncertainty is widely recognized, and students apply acceptable objective procedures to obtain knowledge, using biased or unbiased information from either authorities or peers as evidence.
- **Contextual knowing**: All knowledge is uncertain, authorities are not all-knowing and procedures for forming judgments do not always apply. Form unbiased judgments on the basis of available evidence within context. For example, scientific models are only as good as the data used to construct them.

These stages provide evidence that students' intellectual growth is a progression in which reflective learning can help them to recognize the importance of evidence in making judgments. Reflective learning exercises can help students to develop their intellect by progressing through these four stages of knowing, which provides an additional benefit to those mentioned above.

Our research questions are as follows:

1. How extensively did our students identify the importance of what they learned in our course?
2. Where else did students identify opportunities to use the skills learned in our course, and how well were these opportunities supported by evidence, such as specific examples*?*

METHODOLOGY

A weekly reflective journal assignment was given to approximately 50 students during each of our fall and spring semesters, using a template containing sixteen rows and three columns. Each row corresponded to a specific week in the semester. The columns contained responses to these questions: *What did you learn? Why is it important? Where else could you use it?* During each week, students identified a specific skill, concept or insight that they learned during that week, explained its importance to them, and gave an example of where else they could use it, e.g., in another course, on the job or at home. Each 3-4 week submittal was graded on a scale of 0-2 in 0.25 increments, utilizing a qualitative assessment of the student's level of effort and insight. The sum of the five intermediate journal grades comprised 5% of the student's course grade.

PRELIMINARY RESULTS

The following tables show representative reflective journal entries by students in the fall 2013 and spring 2014 semesters. Table 1 contains "acceptable" entries, Table 2 contains "better" entries, and Table 3 contains "excellent" entries:

TABLE I: EXAMPLES OF "ACCEPTABLE" ENTRIES

What did you learn?	***Why is it important?***	***Where else could you use it?***
What information to look for in an online source to see if it is reliable.	Any information obtained from research should be reputable, so that its use builds credibility.	Knowing what kind of information to look for could be used for any type of research.
The code of ethics that all engineers must follow.	Know the ethics in engineering so as not to break any laws. They are also good personal morals.	Use this code in everyday life, such as keeping the welfare of other humans in mind.
How to do the basics of SolidWorks, such as simple sketches on planes.	It was the first step toward learning more advanced features in SolidWorks.	It is a valuable tool that I will have to use a lot as an engineer designing things.

TABLE II: EXAMPLES OF "BETTER" ENTRIES

What did you learn?	***Why is it important?***	***Where else could you use it?***
How to construct a decision matrix: choosing aspects of a design/project and rating them on their performance or	Engineers needs a formulaic and unbiased approach to choosing one aspect of a design over another.	In choosing what clothes to wear on a particular day, by considering various factors, including weather, comfort and

feasibility of each aspect.		appearance, you are, in effect, using a decision matrix.
How to model basic parts in SolidWorks; how to construct a materials list and cost estimation.	SolidWorks helps engineers to represent their designs digitally, which makes editing them much easier. Cost estimates are important to give you a rough idea of how much the materials and labor will cost to produce a product.	SolidWorks can be used to design parts and objects that I may need for Senior Design. Cost estimates can be used for everything from school projects to home improvement, such as installing new tile in a bathroom.
The rewards of submitting and presenting our final report.	It is important to recognize the value of hard work. Our team has created a final project that is more professional than any other projects that I have completed.	There are certain to be late nights and long hours of work at times in the engineering workplace, but it is the passion for the material that drives engineers to these extremes.

TABLE III: EXAMPLES OF "EXCELLENT" ENTRIES

What did you learn?	***Why is it important?***	***Where else could you use it?***
More about my fellow team members and their expectations for our project, through our team contract.	Team contracts hold all team members accountable. They also specify team goals and individual tasks, which is especially helpful when completing a long term project.	A roommate contract: they designate boundaries and inform other residents how you expect the house to be maintained.
Orthographic views, e.g., drawing the missing view and correcting views that were drawn improperly.	If there is a complicated part that one engineer is trying to explain to another, then the orthographic view can be used to explain some of the details.	When buying something online, it would be useful to be able to put all of the views together to understand the full picture.
Be willing to ask for help when you need it.	Asking for help with a difficult problem can save you hours of work.	Asking for help creates humility, an important quality for all people, but also helps you interact with other people as a team.

DISCUSSION

Since our students were not limited in identifying specific course topics for reflection, the first columns in Tables 1, 2 and 3 contain both procedures, (e.g., graphics, decision matrix) and insights (e.g., team dynamics, benefits of a quality written report). In terms of Felder and Brent's levels of intellectual development [5]-[6], the reasons for importance in Table 1 illustrate the Absolute and Transitional levels, because importance is based on either prescribed information that does not deviate, or on a procedure for deciding whether an online source of information is valid. In Table 2, the importance of procedure in the first and second entries shows Transitional knowing, but the realization of quality and how to achieve it is a student-based judgment, which indicates a possible entry into Independent knowing. The entries in Table 3 are also indicative of Independent knowing, at least in its early stages, although the goals and commitments identified in team contracts may be biased by the intentions of team members to present the best possible outlook, regardless of their actual motives. The absence of Contextual knowing in Tables 2 and 3 arises from our observation that the student did not sufficiently state the conditions under which the skill or insight was important, with or without the implication that other conditions might diminish importance.

The quality of evidence, in terms of specificity, which supported the examples of where else specific knowledge could be applied varied widely among the entries in Tables 1, 2 and 3, and influenced the journal grades to a major extent. The entries in Table 1 show very little specificity in its examples, while those in Tables 2 and 3 indicate that the student put in time and effort to identify examples that were useful to them, but not necessarily obvious. This shows a principal lesson in the value of reflection: the most valuable insights are seldom the most obvious, and often reveal widespread applicability. The last entry in Table 3, in particular, shows that this student realized not only an outlook that was useful in any course involving teamwork, but a life skill influencing character.

CONCLUSIONS AND RECOMMENDATIONS

Since we are dealing with first year students, we did not expect that their reflective journals would contain many entries that could be considered examples of Contextual knowing. However, the fact that some of the entries provide evidence for the applicability of skills or insights to other courses, work or everyday life indicates that a large number of our students could attain this level of intellectual development with time and maturity. It also provides further evidence that the first year engineering experience is not too early to introduce and facilitate the practice of reflective learning.

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