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Meeting the NAE Grand Challenge: Personalized Learning for Engineering Students through Instruction on Metacognition and Motivation Strategies

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Introduction

The pace of technological change is ever increasing. In one hundred years, we went from horse and buggies to space travel; from cross-country mail that required weeks to instantaneous communication by electronic means; from outhouses and hand-pumped wells to sophisticated sanitation and water systems, nationwide. If history is a guide, the next one hundred years will produce even more incredible technological advances. One thing is certain—engineering graduates of today must be prepared for a lifetime of learning and adaptation.

This project aims to advance personalized learning by helping students to understand and regulate their own learning. The project is designed to equip our students with the knowledge, skills, and attitudes of self-directed *lifelong* learning. Earlier research on learning styles, motivation, self-regulated learning, and lifelong learning serves as the foundation for this project. Strategies for achieving the intended student learning outcomes include:

- Develop *online learning* modules that i) give students first hand experience of the influence of learning style and motivation on learning; ii) present tutorials on metacognition and motivation;
- Implement a *course construction activity* in which students create learning materials appropriate for their preferred learning style on a relevant course topic of their choosing;
- Implement a *research design* that deploys the modules and course construction activity in selected sections of two courses such that the effect of multiple versus single exposures is assessed.

Module Development

We have developed and tested the online modules on learning styles and motivation. In the beginning of the learning styles module, students take a learning style questionnaire to determine their preferred learning style(s). We chose the Barsch Inventory[1] for our e-learning module because it is simple and can be used free of charge with permission. It identifies four learning styles: visual, auditory, tactile, and kinesthetic. Figure 1 summarizes the content of the learning styles module.

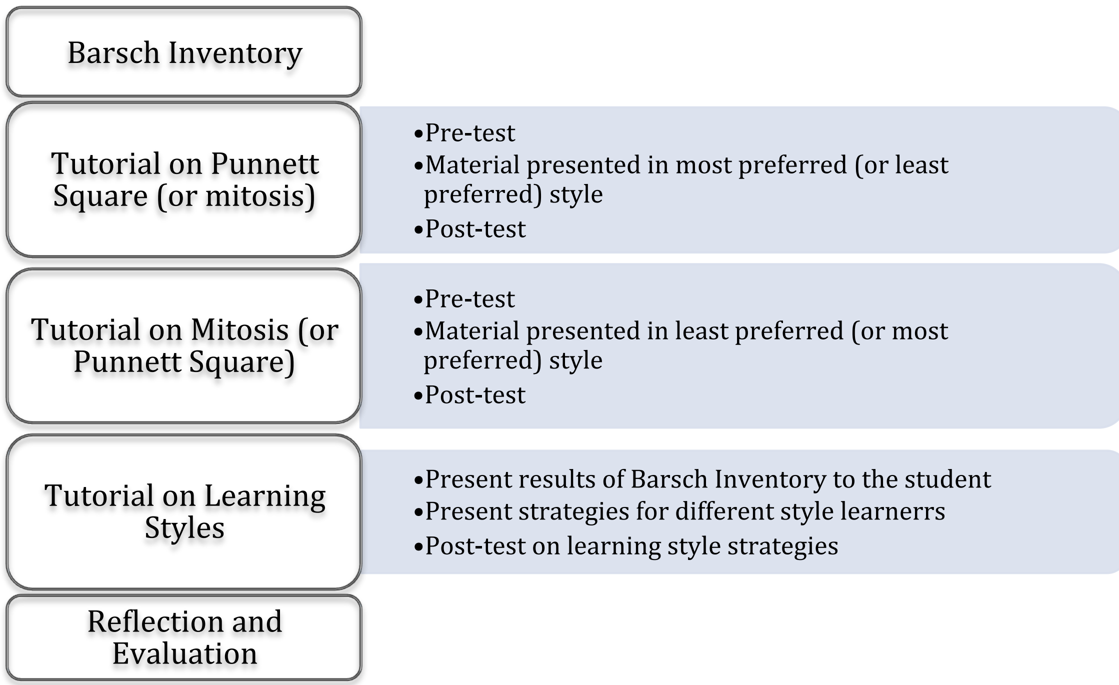

Figure 1. Outline of learning styles module

The learning styles module teaches about two biology topics—Punnett Squares and mitosis. Four presentations were prepared for each topic—one for each learning style. Students are presented with information about one of the topics in their most preferred learning style and the other topic in their least preferred learning style. For the visual presentations, the module presents PowerPoint slides. For the aural presentations, the module directs students to Khan Academy videos; these combine both visual and auditory. For the two topics selected, a purely auditory presentation would probably have been ineffective. For the tactile presentation, the module asks students to view a video and take notes. For the kinesthetic presentation, the module presents interactive flash animations that were created specifically for the module.

After the learning styles questionnaire, students take a pre-test on one of the biology topics, then proceed through a tutorial on the topic, and then take a post-test. This procedure repeats for the second biology topic. Next, the students learn of their Barsch Inventory results, and they go through a tutorial about learning styles and suggested strategies for different style learners. The module concludes with evaluation and reflection questions.

The motivation module follows a similar format as the learning styles module. Figure 2 outlines the content of the motivation module. It starts with the Motivated Strategies for Learning Questionnaire (MSLQ)[2]. Students are asked to consider the course in which they are assigned the module when answering the questions about motivation. This questionnaire is based on an expectancy-value theory for motivation and measures control beliefs, extrinsic motivation, intrinsic motivation, self-efficacy, task value, and test anxiety.

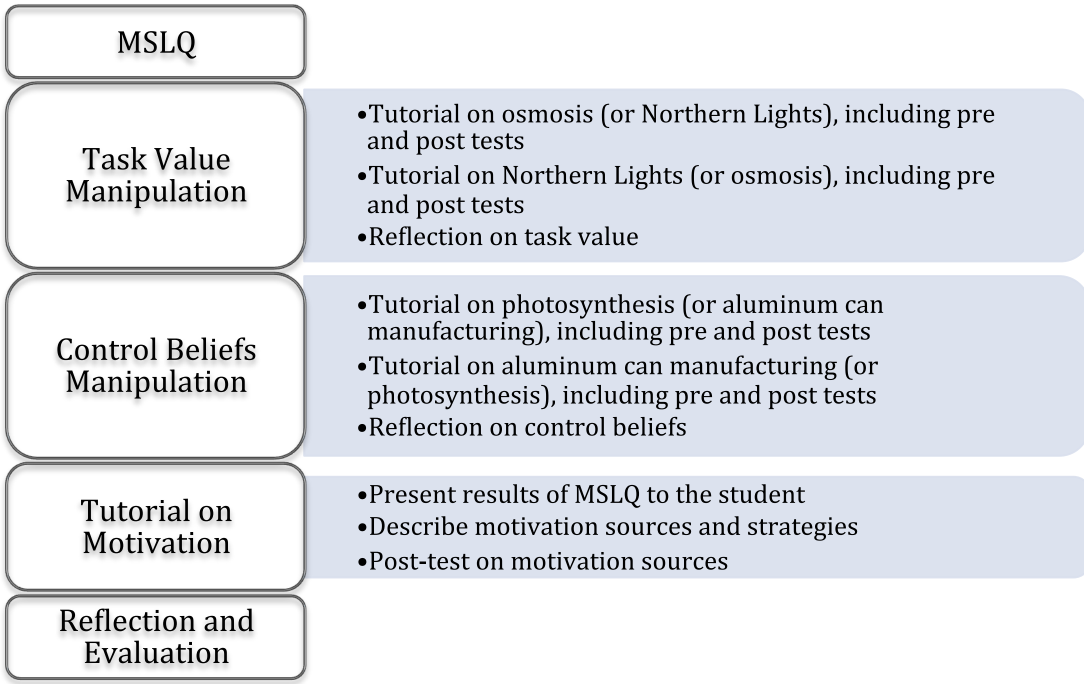

Figure 2. Outline of motivation module

The module then has learning tutorials in which two components of motivation are manipulated: task value and control beliefs. To manipulate task value, the module has tutorials on two quite different topics that would have different levels of interest for students: osmosis and the Northern Lights. Before the task value tutorials, the module asks students to rate their interest in the two topics. We anticipated that the Northern Lights topic would be more interesting for most students, but it was not for all students, and it was not necessary for that to be the case. After completing the two tutorials that include pre and post tests, students answer questions about their reflections on task value. For the control beliefs manipulation, the module includes two topics about which we anticipated an engineering student would have different confidence levels. The module introduced the photosynthesis topic by stating that it would be difficult material for a mechanical engineering student. The introduction to the aluminum can manufacturing tutorial indicated that it would be easy for a mechanical engineering student to learn.

Next, the module informs the student about their scores on the MSLQ, and it describes where motivation comes from. It then gives learning strategies that address the components of the MSLQ[3]. Like the learning styles module, the motivation module concludes with a series of questions asking students to reflect on the module experience and finally evaluate the module with suggestions for improvement.

Data Collection

The modules collect a significant amount of data including performance on the pre and post quizzes, responses to module evaluation questions, and responses to reflection questions. In addition, we are administering a "brain test"[4] and the self-directed learning readiness survey (SDLRS)[5]. The brain test gives a measure of left and right brain dominance. It reports scores for four quadrants. Quadrant A is an indicator of analytical thinking. Quadrant B is an indicator of procedural thinking. Quadrant C is an indicator of interpersonal thinking. Quadrant D is an indicator of imaginative thinking. Quadrants A and B are in the left brain with C and D in the right brain. The SDLRS gives a composite score on lifelong learning readiness. Hoban, et al.[6] used the SDLRS to identify four dimensions of lifelong learning readiness: curiosity, self-confidence in learning abilities, responsibility for one's own learning, and the attitude that learning is a tool for life.

Students in a second year manufacturing class and a third year design class have been recruited to participate in the study. Data has been collected in the spring 2012 and fall 2012 semesters. Participants take the brain test once early in the semester. The SDLRS is used to test the effectiveness of the learning styles and motivation modules as an intervention for improving lifelong learning. Some participants take it as a pre-test before taking the modules while others take it as a post-test.

Figure 3 compares the brain test results of the participants in the 2nd and 3rd year classes. As expected, the mechanical engineering students in these classes have higher scores for Quadrants A and B. Also of note is that the scores are more left-brained for the 3rd year students than for the 2nd year students. This is consistent with the work of other researchers who find that engineering students become more left-brained as they proceed through an engineering curriculum[7].

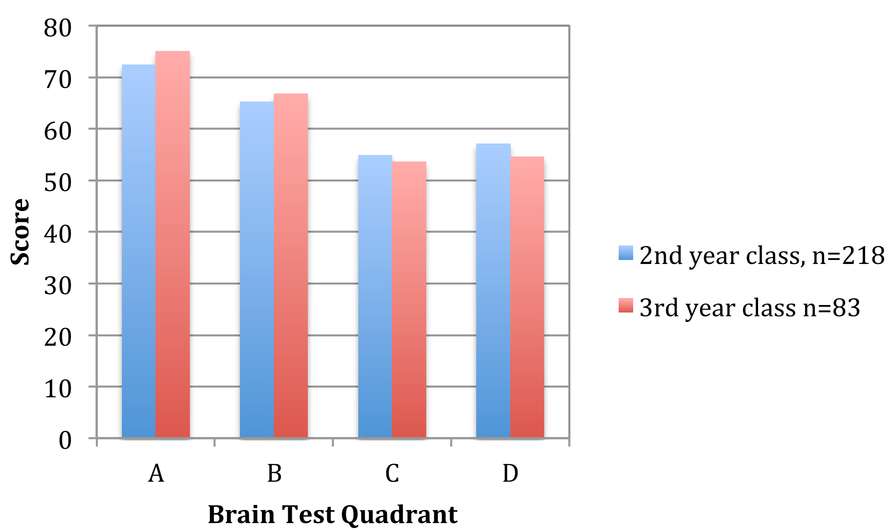

Figure 3. Comparison of brain test scores for 2nd and 3rd year class students

Figure 4 compares the results for male and female participants. Note that the female students have higher quadrant C scores. This difference is statistically significant at a level of p=0.02.

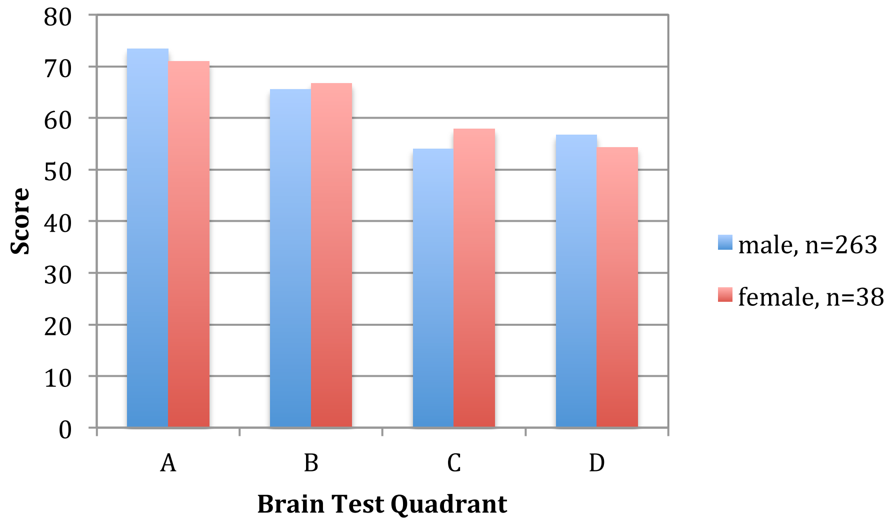

Figure 4. Comparison of brain test scores for male and female students

Recall that the purpose of the modules is to improve lifelong learning ability. To test their effectiveness, we compared SDLRS test scores before and after taking the modules. In the first semester of data collection we attempted to have students take the SDLRS both before and after the modules (early and late in the spring 2012 semester). A large number of students took the SDLRS early in the semester, but, ultimately, far fewer took it a second time. Another problem was that some students scored much differently on the test the second time, indicating, perhaps, that they rushed through it. In the fall semester, we asked students to take the test just once, assigning them to a pre or post condition based on the first letter of their last name.

The average SDLRS score for the 258 students who took the test as a pre-test was 216 (50^{th} %ile for adults) while the average for the 79 students who took it as a post-test was 221 (57^{th} %ile). A two-tailed (with the assumption of equal variance) t-test of the difference between these two groups produced a p value of 0.074. The four factors from the SDLRS were also compared. Figure 5 shows the comparisons of the average values between the pre and post groups.

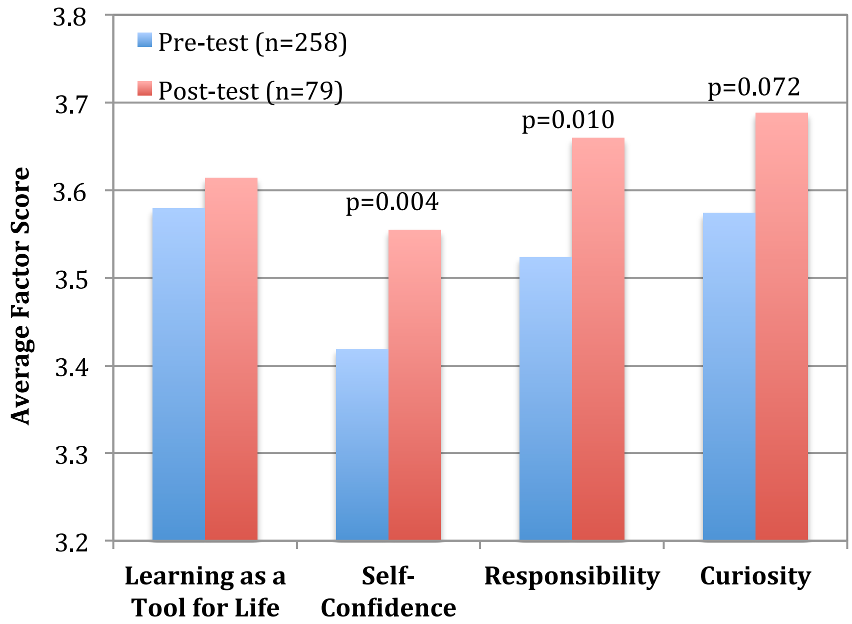

Figure 5. Comparison of SDLRS factor scores for the pre and post-test groups

This is an encouraging result but we need to look more closely at the two groups of students. For example, the students who took the post-test had to follow through and complete the two modules. At least a few of the pre-test students started but did not complete the two modules (which took much longer to do than the SDLRS). In other words, students doing the post-test may have already started with a higher level of traits such as responsibility and curiosity.

In a second analysis we compared the SDLRS results of the 2nd year (typically) manufacturing class and the third year (typically) design class. In the second year course, the average pre and post scores were 215 and 219, respectively. In the third year course, the average pre and post scores were 218 and 223, respectively. The differences between the second year takers and the third year takers are not quite statistically significant (p=0.16). Interestingly, the only factor with a statistically significant difference between the older and younger students (combining both pre and post test takers) is self-confidence. Figure 6 shows the comparison of the four factors for four groups of students: the pre and post test takers in the second year course and the pre and post test takers in the third year course.

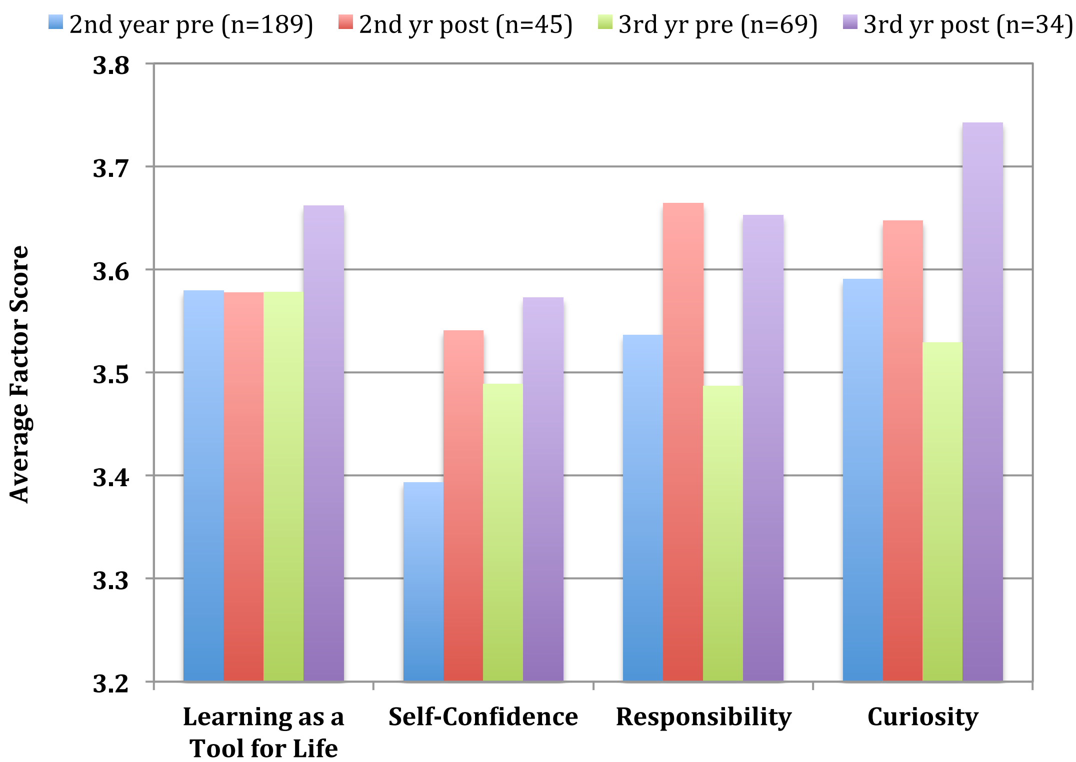

Figure 6. Comparison of SDLRS factor scores for 2nd and 3rd year class students

Thus far, 38 women and 299 men have taken the SDLRS. The average score for the women was 221 while the average for the men was 216, but this difference was not statistically significant. Looking at the four sub-factors revealed no statistically significant differences between the genders.

Conclusions

With the goal of improving student awareness and lifelong learning readiness, the project team has developed two computer modules that teach about learning styles and motivation. The modules take between 30 and 60 minutes to complete and thus represent a very short intervention. More than 150 students have taken the two modules. We are measuring brain test results and lifelong learning readiness in the second and third years of the mechanical engineering curriculum. As an intervention, the evidence so far indicates the modules may be having a modest effect on lifelong learning readiness. We are examining additional data collected by the modules to identify ways to improve the modules.

Acknowledgment

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