Gender Differences in Adaptive Expertise: Evaluation of a challenge based HPL biomedical engineering curriculum

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Abstract – **This paper investigates gender differences (n=54) in adaptive performance and beliefs in a nontraditional "How People Learn" (HPL) challenge based biotransport course at a large public university. The HPL challenge framework is similar to problem-based or inquiry-based learning, but with a significant emphasis on knowledge taxonomy and formative feedback. The course consisted of a series of 10 challenges. Performance was measured on three dimensions (knowledge, innovation, and adaptive expertise) at three different time points over the course of the semester. The results showed that all students significantly improved on all three performance dimensions over time. Student adaptive beliefs were measured using a Likert scale self-reporting survey. There were significant gender differences in performance, but no gender differences in beliefs. Females had lower initial performance, but showed more improvement. By the end of the course, males and females performed similarly on all three measures. These results suggest that HPL curriculum/instruction can help mediate the gender gap in SMET education.**

Index Terms – Gender, Adaptive Expertise, Transport, How People Learn, Problem-based Learning

OBJECTIVES & THEORETICAL FRAMEWORKS

In an age where technology is developing at an exponential rate, it is becoming even more important to educate engineering students with sufficient background knowledge and the ability to be flexible, innovative and lifelong learners. One way these traits are currently defined is as adaptive expertise. Demographic trends are also making it more important to educate more diverse student populations. Traditionally, students of color and women have been underrepresented in postsecondary engineering [1]. As curricula and educational frameworks are improved and implemented, it is important to the public good to simultaneously evaluate their impact on students who have been traditionally marginalized. This study evaluates gender differences in the development of adaptive expertise in a non-traditional HPL [How People Learn] challenge based biomedical engineering classroom.

Adaptive Expertise

Reference [2] defines an adaptive expert as "an individual who possesses the content knowledge of an expert, but who in addition displays specific cognitive dispositions that augment and enhance their ability to effectively utilize and extend their content knowledge." Classic research in adaptive expertise defines its opposite as routine expertise [3]-[4]. Routine expertise is the development of a skill that can be repeated without much cognitive effort. Conversely, adaptive expertise requires understanding and flexibility.

Experts often access what they know, what they don't know and what they will need to learn in order to solve the problem. In addition to differences in knowledge, experts and novices often differ in knowledge organization and retrieval. Experts' knowledge is generally organized around key principles aiding in the retrieval process.

Adaptive Expertise has also been studied with history experts [5]. Two history experts were given primary source documents dealing with Abraham Lincoln and his view of race. Both historians were American history professors of equal recognition. However, the first historian specialized in the Civil War era and was very familiar with Lincoln and the era, and the second historian had domain knowledge but not as specialized as the first. The experts read the documents and used the "think-a-loud method" to aide the study of their process. The second historian is an example of adaptive expertise. The most notable thing was how he identified what he did not know and learned from that.

Gender Equity

A large scale qualitative study found that female Science, Math, Engineering, and Technology (SMET) students are more sensitive to poor teaching in college classrooms [6]. Empirical studies have shown that compared to traditional teaching methods, HPL leads to increased student learning and development [7]-[12]. Another large qualitative study showed that women learn better when knowledge is connected. They offer recommendations that problem solving be modeled in front of the classroom [13]. Both problem solving and connected knowledge were important parts of the HPL

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curriculum. HPL also aligns with recommendations for "female friendly" science instruction [14]-[15]. We hypothesize that HPL will increase the three performance measures for all students and have unexplored potential to improve the achievement gap for women and under-represented minorities in engineering.

Studies have shown that there are gender differences in beliefs around math and science. In an NSF report, high school boys and girls differed most in their attitudes about science (girls liked science less, were less confident about their abilities and saw it as less important to their futures) regardless of achievement level [16]. Eccles' model explains both the social and psychological factors influence women's career goals and achievement level. Important components in this model are expectation for success, value placed on the field of science and on other fields perceived as more people related, and parental influence, gender stereotypes [17] It is plausible that adaptive beliefs impact performance in adaptive situations. We hypothesize that gender differences in beliefs could play a role in gender differences in performance.

METHODS

Challenges

The Biotransport course requires a knowledge base from biology/physiology, physics, applied mathematics, (specifically differential equations) and fundamental engineering principles. The course combined all three areas of transport phenomena, momentum transfer (fluids), heat transfer, and mass transfer, taught in that order. Special attention was paid to the taxonomy by the professor during both the course and the curriculum design to assure that students developed understanding of general principles and other core knowledge.

The course consisted of 10 challenges (see Table I.) following the STAR Legacy Cycle format [11]. The SL cycle has six phases: Challenge Presentation, Generate Ideas, Multiple Perspectives, Research and Revise, Test Your Mettle, Go Public. Generate Ideas is typically some sort of brainstorming activity to get students to think about what will be involved in the challenge, what do they know, what do they need to know, and what resources they might use. This engages the students thinking prior to hearing a lecture, reading text or some other form of media in the next multiple perspectives phase. In the research and revise phase, students are encouraged to use the information they gained in the multiple perspectives phase to revise their own thinking and ideas from the generate ideas phase and consult more resources to help them solve the challenge. This phase acts as a formative assessment where students can use information about what they did right or wrong and expand on it. Test Your Meddle is used as an aide to help students monitor their own understanding. In the Go Public phase, students report and validate their findings in some form to the rest of the class. This can be in the form of an oral presentation, poster, or a letter to an official (which may not be group oriented).

Participants

After a brief introduction of the first challenge and active generate ideas exercise, students were informed about the goals and purpose of our study. Of the 72 students in the class, 54 students (34 males and 20 females) signed consent forms to participate in the study. Most of the students were juniors or seniors in Biomedical Engineering so they are approximately 20-21 years old.

Study Design and Coding

Student performance was measured on three exams given throughout the semester. Each exam consisted of three types of questions: knowledge, innovation, and application. The knowledge questions were traditional plug and chug type problems similar to end of the chapter problems in most transport textbooks. The innovation questions were very challenging questions written to see if the students could apply their knowledge and understanding of general principles to a very challenging novel problem. In these problems students were instructed to define and set up the problem to get a solution, but they were not expected to actually carry out the solution to get a numerical answer. The application problems were designed to combine both knowledge and innovation. They were written as novel and challenging, but students were expected to arrive at a complete numerical solution.

The problems were coded for correctness by the professor and the engineering teaching assistant. Reliability was not established for this pilot study.

A pretest/post test design was used to measure student beliefs. Students were given a survey to assess their adaptive beliefs [2]. The survey measures four dimensions of adaptive beliefs: multiple perspectives, metacognition, goals and beliefs and epistemology. Multiple perspectives assesses whether students use different approaches or consider more than one way to solve a problem. Metacognition evaluates whether students question themselves and their own understanding of a problem or information. Goals and Beliefs tests how students approach challenging problems and their personal beliefs about intelligence and success in engineering (are they innate or an artifact of hard work). The epistemology section tests students' perception of the nature of science.

The survey was coded using a 5 point Likert scale from agree strongly to disagree strongly. Items that were negative indicators for adaptive expertise were reversely coded. Dimensions did not have equal numbers of questions so the scores within each dimension were averaged out of a total of 5 points.

TABLE I
CHALLENGES (IN ORDER PRESENTED IN CLASS)

Challenge	Fluids	Heat	Mass	Challenge Description
Heart Lung Machine I	X	X	X	Advise a biomedical company on what major components they must consider in their design of a machine used to take over the functions of the heart and lungs to add oxygen and remove carbon dioxide from the blood and to pump the blood through the patient's vascular system during open-heart surgery.
Blood Doping	X			Prepare a report to an athlete on the advantages and dangers of blood doping, increasing the percentage of red cells in circulation.
Cilia & Mucous Flow	X			Develop set of fluid flow equations that describe the movement of mucus in the respiratory system (account for the effects of coughing with your model equations).
Asthma/Pulmonary Function	X			Develop a basic model for the flow of air that can be applied to rigid airway components and generalize it to account for the fact that some airway components are flexible. (Incorporate into the model some of the effects of asthma on respiratory function.)
Post Mortem Interval		X		Evaluate whether the analysis of a Post Mortem Interval (PMI) by a forensic scientist is credible, and, if not, what corrections need to be made and/or what additional information needs to be considered.
Heart Lung Machine II		X		A patient suffers from brain damage during heart surgery utilizing a Heart Lung Machine (HLM). The alleged cause of the brain damage was that the perfusion was terminated at a temperature at an improper temperature, and that the perfusionist's data log was falsified to cover the error. The students are asked to analyze the available data and to determine if is possible to prove whether the data were falsified.
Coffee Spill		X		Determine appropriate coffee temperature based on McDonald's drive thru coffee spill lawsuit in New Mexico
Hot Water Standards		X		Determine appropriate hot water heater temperature standards based on eliminating/reducing infant mortality from hot water burns.
Space Suit		X		Design spacesuit that has an automated thermal control. Identify the most important factors that will have to be considered for the design of an automated thermal control garment and calculate some initial performance values for selected system components.
Sundae Glucose Membrane Transport			X	Determine the rate of glucose uptake into tissues from the blood stream via transport in the capillaries from eating an ice cream sundae prior to Thanksgiving dinner

RESULTS AND CONCLUSIONS

There was not a main effect of gender, but there were gender differences in the development of innovation. Both groups improved on the innovation measure over time. Females improved more on this measure than the males, but both groups were very similar on the final exam. Gender was not significant on the knowledge and application performance measures. There were no significant gender differences in beliefs. Beliefs remained relatively stable, but due to a small deviation among students' pre/post test differences were significant over time on the two of the four belief dimensions, multiple perspectives and metacognition.

Performance

We analyzed the knowledge, innovation, and application scores using a 2 x 3 repeated measures ANOVA on each measure with gender (M,F) as the between-subjects factor and time (Exam 1, 2, 3) as the within-subjects factor. We found that all students improved over time on all three measures (see Figure 1.)

Males and females performed similarly overall. However, they performed differently at different times on the innovation measure (see Figure 1.) On Exam 1, males outperformed females. However on Exam 2, females more improved to outperform males. This interaction between time and gender was significant, $F(2,91)=4.4$, $MSE=296.7$, $p<0.02$.

Beliefs

Gender was not significant on any of the four belief dimensions. Table II shows gender results on the beliefs survey. Time was significant only on multiple perspectives $F(1,44) = 4.1$, $MSE = 0.35$, $p = 0.05$ and metacognition $F(1,44) = 4.4$, $MSE = 0.71$, $p = 0.04$. Both males and females improved on the multiple perspectives dimension and received lower scores on the metacognition dimension (see Figure 2.)

TABLE II
BELIEFS SUMMARY BY GENDER

Time	Dimension	Males Mean	Males SE	Females Mean	Females SE
Pre	Multiple Perspective	3.1	0.09	3.0	0.10
	Metacognition	3.8	0.12	3.7	0.10
	Goals&Beliefs	3.3	0.08	3.3	0.09
	Epistimology	3.9	0.07	3.8	0.10
Post	Multiple Perspective	3.3	0.10	3.1	0.08
	Metacognition	3.7	0.11	3.5	0.08
	Goals&Beliefs	3.4	0.11	3.3	0.08
	Epistimology	3.7	0.09	3.8	0.14

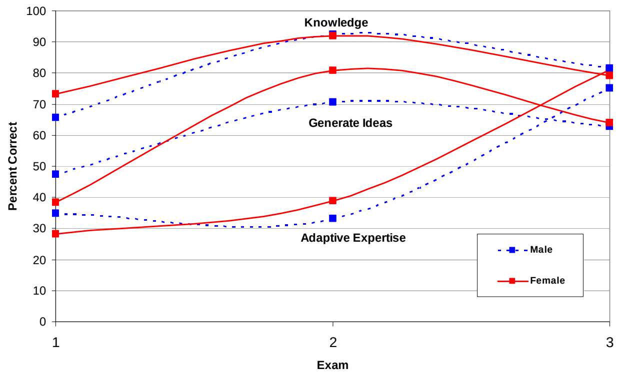

FIGURE 1
STUDENT PERFORMANCE MEASURES BY GENDER

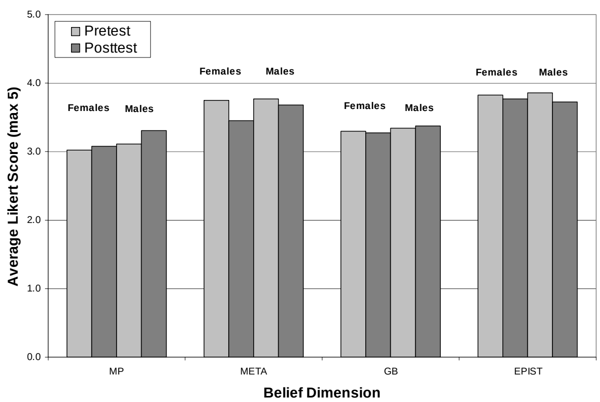

FIGURE 2
GENDER DIFFERENCES IN BELIEFS

EDUCATIONAL IMPORTANCE

Performance

Although the core content was similar, this course differed from most traditional engineering courses in instructional methods and the way the content was delivered. The course specially focused on giving students practice in using new knowledge in challenging, innovative problems with the aim of promoting the development of adaptive expertise. Similarly to other empirical studies, our research shows that the HPL framework as implemented in this course was effective for students of both genders. The significant improvement of females after the first exam suggests that HPL is particularly effective for female students and that these gains are not at the expense of other students. The results of this pilot study imply that HPL shows promise in gender equity, but further work in this area is necessary to replicate and validate this hypothesis.

Beliefs

The lack of gender differences in adaptive beliefs suggests that beliefs are not a key factor in adaptive performance. Overall beliefs remained fairly stable with little variation between genders. This could be an artifact of the survey instrument that was used. Future research is necessary to either validate this or find a more effective beliefs assessment tool.

ACKNOWLEDGMENT

This work was supported primarily by the Engineering Research Centers Program of the National Science Foundation under Award Number EEC-9876363.

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