A Simulation-Based Approach for Increasing Women in Engineering

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Abstract: Institutions have historically struggled with retaining women in engineering. Using epistemic frames as a theoretical framework, we propose that more women would remain in the field if they had authentic engineering experiences. To test this hypothesis, we implemented an epistemic game, Nephrotex. Our controlled study indicated that (1) Nephrotex women developed positive associations and (2) focused on engineering design. Further study is needed to determine if this positive design experience leads to persistence in engineering.

Introduction/Theory

Educational institutions at all levels have historically struggled with motivating and retaining women in engineering. The single biggest drop in engineering enrollment occurs between the freshmen and sophomore year (Atkinson & Mayo, 2011). First year undergraduate courses thus play a pivotal role in a student's decision to major in engineering, but these courses aren't retaining women. Recent studies show that women are generally more interested in STEM when it involves teamwork, collaboration, and professionalism, and social impact (Thom, Pickering, & Thompson, 2002; Zastavker, Y Ong & Page, 2006).

An alternative hypothesis is that some students opt out of engineering because of the basic math and science courses that are the focus of the first year curriculum (Lumsdaine & Lumsdaine, 1995). In this view, more first year students would remain in the field if they had authentic experiences of the engineering profession such as engineering design—the most central aspect of the profession (Dym, Agogino, Eris, Frey, & Leifer, 2005) in the form of a professional practicum.

Shaffer (Shaffer, 2007) has characterized the learning that takes place in practica in terms of an epistemic frame. Epistemic frame theory suggests that every profession has unique collections of skills, knowledge, identities, values, and epistemology that construct an epistemic frame. Developing an epistemic frame means making connections between these elements. Thus, the goal of a professional practicum is to build a professional epistemic frame—to develop the ability to think like a professional. However, first year students do not have many opportunities to participate in practica.

One approach to this problem are epistemic games—computer simulations of professional workplaces where novices can solve real-world problems without needing to first master basic domain content. The complex knowledge and skills that students do not yet have are embedded in the tools that novices use in the simulation (Bagley & Shaffer, 2009). In this study, we designed and tested an epistemic game for engineering called Nephrotex. This study asks: Did attitudes towards engineering careers change more positively among women who played Nephrotex? Were students who made more connections with engineering design more motivated to continue in engineering than those who made more connections with collaboration and professionalism?

Methods

In Fall 2010, 120 students enrolled in an introductory engineering course. In total, 45 students (13 female, 32 male; treatment group) participated in Nephrotex. The remaining 75 students (24 female, 51 male; control group) participated in team-based research projects.

Two sources of data were collected for this analysis of Nephrotex: (1) students' pre and post survey responses and (2) students' discourse in the chat program. We conducted a PCA on survey responses. The mean scores on the significant component for women and men students were calculated, and t-tests were used to compare the percentage of students that had positive gains from pre to post survey.

We coded the discourse using codes using epistemic frame theory as a guide for professional practices. We used Epistemic Discourse Coding, an automated coding process that has been validated by comparing hand-coded utterances by human coders to the automated coding system. Cohen's kappa scores were between .80 and .98 between the automated system and human coders (D'Angelo et al., 2011). We used Epistemic Network Analysis (ENA) on the coded discourse. This analysis tool measures relationships between epistemic frame elements by quantifying the co-occurrences of those elements in discourse (Shaffer & Chesler, 2009). Here we used ENA to measure students' development of connections made between skills, knowledge, identity, values, and epistemology.

Results

The percentage of women in Nephrotex that had a positive change in mean scores (M = 72%, SD= 19%) were significantly larger than the percentage of women in the control group that had a positive change in mean scores (M = 35%, SD = 22%, $p < .05$) (figure 1).

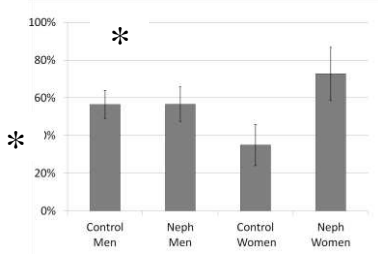

Figure 1. Percentage of students that had a positive increase in mean scores from pre to post on *positive view of engineering careers.* (Mean ± Standard Error, * p<.05)

ENA component 1 (ENA1) and ENA component 2 (ENA2) were significant. Items that loaded negatively on ENA 2 are related to data analysis and professionalism, and items that loaded positively on ENA 2 are related to engineering design. Students in Nephrotex who made more connections between the skills, knowledge, and epistemology of engineering design and other engineering frame elements showed positive change in *positive view of engineering careers* from pre to post survey. In other words, ENA2 scores significantly predicted positive view of engineering post scores when controlling for pre scores ($\beta = 1.789$, $p < .05$, $R^2 = .411$). Thus, results from this study show that women who participated in Nephrotex viewed a career in engineering more positively than women in the control group, and these changes were associated with engineering design activities in the internship.

Discussion

The question we address in this study is whether these women showed an increase in their positive associations with engineering after engaging in authentic engineering design, developing an engineering epistemic frame, and as a result having a positive view of engineering. This is in contrast with a more traditional hypothesis, enacted in this study's control condition and in many current first year undergraduate courses of collaboration and social value leading to a positive view of engineering.

The results above suggest that women in the Nephrotex condition who focused on design had a more positive view of engineering than women in the control group. We therefore propose the *epistemic persistence hypothesis* (figure 2). Further study is needed to test the epistemic persistence hypothesis for first year undergraduate women.

Figure 2. Epistemic persistence hypothesis.

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