Computers & Education 53 (2009) 209–215

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Changing middle-school students' attitudes and performance regarding engineering with computer-based social models

E. Ashby Plant, Amy L. Baylor *, Celeste E. Doerr, Rinat B. Rosenberg-Kima

Department of Psychology, Florida State University, P.O. Box 3064301, Tallahassee, FL 32306-4301, United States

ARTICLE INFO

Article history:
Received 3 October 2008
Received in revised form 12 January 2009
Accepted 16 January 2009

Keywords:
Social model
Interface agents
Self-efficacy
Mathematics
Engineering
Persuasive technology

ABSTRACT

Women's under-representation in fields such as engineering may result in part from female students' negative beliefs regarding these fields and their low self-efficacy for these fields. In this experiment, we investigated the use of animated interface agents as social models for changing male and female middle-school students' attitudes toward engineering-related fields, their self-efficacy for these fields, and their math performance. Students interacted with either a female or a male computer-based agent or they did not interact with an agent. The female agent increased interest, utility beliefs, self-efficacy, and math performance compared to control and, for boys, decreased stereotyping. Mediational analyses indicated that the female agent facilitated interest and math performance by enhancing self-efficacy. The findings indicate that interface agents may be used effectively as social models for influencing attitudes and beliefs and supporting performance.

1. Introduction

Women have achieved increasing inclusion and success in professions that were formerly occupied primarily by men. Fields such as law and medicine, which were historically heavily male dominated, have achieved sex equity over the past 30 years (Goodman et al., 2002). However, women remain under-represented in the field of engineering. For example, only 8.5% of all professional engineers are women, although women constitute close to half of the total workforce (Goodman et al. 2002). A 2003 National Science Foundation (NSF) report indicated that women account for only 20% of the undergraduate enrollment in engineering programs even though they are more likely to attend college than men (also see National Science Board, 2006). This absence of women in engineering is also evident in doctoral programs where men are four times more likely than women to earn a doctoral degree in engineering (National Science Board, 2006). Thus, it is important to uncover ways to encourage greater participation by women in engineering-related fields.

The current work explores whether using computer-based, anthropomorphic interface agents can increase young women's interest and performance in engineering-related fields through social modeling. Previous work indicates that interface agents can positively influence college-age women's beliefs about and interest in engineering (Baylor & Plant, 2005; Rosenberg-Kima, Baylor, Plant, & Doerr, 2008). This work expands upon this previous work in several ways. First, we explore whether using interface agents as social models is effective for a younger audience of middle-school or junior high students. Catching young women at an early age is critical because decisions made early, such as which classes to take in high school and college, can have substantial implications for the ability and likelihood of women pursuing engineering in the future. Second, this work examines whether interface agents positively impact young women's performance in engineering-related fields and, specifically, mathematics. Although the previous work indicates that agents can positively influence attitudes, there is little evidence that they can positively impact performance. In addition, we examine whether any impact of the agents on the students' interest and performance that we find is due to the positive implications of the intervention on self-efficacy and stereotypes about women and engineering. Finally, we investigate how the interface agents and their message influence young men's interest and performance in engineering-related fields. Ideally, any approach that positively influences female students would also encourage male students (or at minimum not discourage them).

* Corresponding author. Tel.: +1 7032361898.
E-mail addresses: plant@psy.fsu.edu (E. Ashby Plant), amy.baylor@gmail.com (A.L. Baylor).

0360-1315/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compedu.2009.01.013

1.1. Computer-based agents as social models and motivators

According to social learning theory (e.g., Bandura, 1977, 1986, 1997), much of our learning is derived from vicarious experience. In general, people are more influenced by social models that are similar to them or similar to how they would like to be (e.g., Bandura, 1986; Mussweiler, 2003; Schunk, 1987; Wood & Bandura, 1989). Observing another person modeling behaviors can facilitate learning new behaviors and strengthen desired behaviors as well as provide information relevant to self-efficacy through social comparison (Bandura & Schunk, 1981; Schunk, 1987; Schunk, Hanson, & Cox, 1987). When people see another person who is similar to them successfully perform a behavior it can bolster their belief that they too can successfully perform the behavior (Bandura & Schunk, 1981). Similar social models can also influence people's attitudes by helping them to discern whether their attitudes toward a specific thing ought to be favorable or unfavorable, and they can supply information about whether or not tasks are behaviorally appropriate for them (Goethals & Nelson, 1973; Schunk, 1987). Consistent with these ideas, there is evidence that the exposure to successful women in engineering-related fields can increase women's interest and performance in these fields. For example, the percentage of women who major in or get a degree in science and engineering fields is positively related to the percentage of female faculty members in the field (Sonnert, Fox, & Adkins, 2007). In addition, Marx and Roman (2002) found that young women performed better on math tests after being exposed to a highly competent female role model (also see McIntyer, Paulson, & Lord, 2003).

Together, this previous work indicates that in order to improve young women's beliefs, interest, and performance in engineering-related fields, it may be most effective to expose them to young, female social models with aptitude and enthusiasm for engineering. There are, however, difficulties with relying upon human social models to influence young women's beliefs about engineering. The logistics of arranging opportunities for young women to interact with social models can be problematic, especially if the desired model is a female engineer. As Hersh (2000) notes, women in nontraditional fields may already face burdensome workloads that make it difficult to devote resources to mentoring students.

One potential alternative source for persuasive human models is to employ computer-based anthropomorphic interface agents, which are 3-dimensional, fully animated, and expressive characters that provide mentoring within a computer-based learning environment. Such interface agents have been found to be effective in positively influencing students' interest and self-efficacy (e.g., Baylor, 2002a, 2005; Baylor & Kim, 2005; Baylor & Ryu, 2003; Kim & Baylor, 2006), metacognitive awareness (Baylor, 2002b), and attitudes (Baylor & Kim, in press). Recent research has demonstrated that interface agents can have a positive impact on female undergraduates' interest and even self-efficacy regarding engineering (Baylor & Plant, 2005; Rosenberg-Kima et al., 2008). Baylor and Plant (2005) had interface agents provide a persuasive message to undergraduate women that included information about successful women in the field of engineering and challenged existing stereotypes about women and engineering. After the intervention, the young women reported more positive math and science related beliefs, compared to their attitudes at the beginning of the semester and compared to a group of women who did not interact with an agent Rosenberg-Kima and colleagues (2008) used a very similar procedure but randomly assigned the young women to attractive interface agents that varied in age, gender, and whether they were "cool" or more "nerdy". They found that agents that were similar to the young women in age and who were "cool" in dress and hairstyle were the most effective in improving the young women's interest in engineering-related fields and self-efficacy regarding engineering-related fields. In addition, the female agents were more effective in challenging the young women's stereotypes that women were less successful and welcome in engineering-related fields and professions than men. These findings suggest that it may be possible to use a similar procedure to influence younger women as well.

1.2. Stereotypes and self-efficacy

In considering the factors that may influence women's interest and success in engineering-related fields, we considered two key potential factors: stereotypes and self-efficacy. Women and girls generally possess unproductive beliefs about math and the hard sciences. For example, they tend to sex-type science as a masculine pursuit (e.g., Hughes, 2002) and negate the utility of mathematics (Eccles, 1994). Such negative responses to math and the hard sciences may make young women less likely to pursue these areas and may lead them to stop taking classes in these fields from an early age. Engineering and scientific fields are generally stereotyped as unfeminine, aggressive, and as object-oriented rather than people-oriented (Adams, 2001; Lippa, 1998). Engineering is viewed as a field lacking in social responsibility and contributing to environmental problems (Hersh, 2000). Additionally, the current under-representation of women in engineering may foster the impression that engineering is an abnormal career for women (Byrne, 1993). Thus, stereotypic beliefs, in combination with awareness of existing under-representation of women in the field may discourage female students from pursuing engineering careers. However, if young women are reached at a young age, it might be possible to change their unproductive beliefs.

Female students' levels of self-efficacy regarding math, science, and engineering may also affect their intentions to pursue engineering careers. Female engineering students tend to believe they are less competent than their male peers (Goodman et al. 2002). Such negative self-efficacy beliefs about engineering-related skills begin early. Starting in elementary school, young girls frequently underestimate their math ability, even though their actual performance is typically equivalent to that of same-aged boys (Eccles, 1987, 1994; Seymour & Hewitt, 1997) and their computation skills are even slightly better than boys' in elementary school and middle school (Hyde, Fennema, & Lamon, 1990). Low levels of self-efficacy are likely to discourage young women from pursuing these areas and, if they begin early, the negative implications may resonate throughout their academic and professional careers.

Self-efficacy is also likely to affect educational outcomes for women who actually choose to become engineering majors. Goodman and colleagues (2002) found that female engineering students who abandoned their major believed their male peers had greater ability and superior comprehension of concepts than themselves, even though 66% of these female students earned an A or B grade point average. Among female students, the most influential factor that determined attrition was not course grades, but level of self-confidence. Therefore, promoting young women's self-efficacy for math, science, and engineering might support their performance in these areas.

1.3. The current work

The purpose of this study was to test whether computer-based interface agents can serve as effective social models to change middle-school students' attitudes and interest regarding engineering-related fields. Participants were randomly assigned to receive an interactive