Evaluating an Engineering Overview Brochure for Educational Outreach to Elementary Schools

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Abstract

Our modern technology-based society depends on qualified engineers for the development of nearly all products that we see, touch, and smell every day. However, only a minuscule fraction of the U.S. students in elementary through high school grades is aware of the critical role that engineers play in our society and the abundant career opportunities in engineering. Engineering colleges and professional organizations have initiated a wide range of outreach programs to educate U.S. K-12 students about engineering and attract them to engineering programs of study. Brochures or pamphlets that give an overview of engineering are often employed in such outreach programs alongside other mechanisms, such as field trips, engineering open houses, and summer camps.

The goal of the present study was to initiate a rigorous research program examining the effectiveness of overview brochures in improving the perceptions of elementary school students about engineering. An engineering overview brochure was designed and developed by a multi-disciplinary team involving experts in marketing, psychology, education, and engineering. The effectiveness of the brochure for engineering outreach was evaluated with a survey instrument. The survey assessed perceptions relating to student self-efficacy, utility, interest in engineering as well as perceptions relating to gender roles in engineering, and negative stereotypes of engineers.

Introduction

The global economic market demands a large community of qualified engineers in a variety of sub disciplines. However, U.S. students typically demonstrate little interest in pursuing university studies in engineering and subsequent careers as engineers. Whereas over 350,000 bachelor's degrees were awarded in business fields in 2009-2010, less than 100,000 engineering degrees were conferred (Gibbons, 2010; NCES, 2012). Even more staggering, more than half of all doctorate degrees in engineering during the 2009-2010 academic year were awarded to nonresident aliens.

To increase the number of undergraduate engineering majors, engineering professional organizations and U.S. universities have implemented a variety of outreach and recruitment programs (Adams, et al. 2011; Davis, Yeary, & Sluss, 2012; Fantz, Siller, & DeMiranda, 2011). These outreach activities include the integrations of engineering activities in school classrooms (Brophy, et al., 2008; Carberry & Church, 2009; Cunningham, et al., 2007; Göl, et al., 2004), school visits and field trips (Innes, et al., 2012, Molina-Gaudo, et al., 2010; Smaill, 2010), as well as after-school clubs and summer camps (Hirsch, et al., 2010; Karp, et al., 2010; LoPresti, Manikas & Kohlbeck, 2010; Mehrizi-Sani, 2012).

These outreach and recruitment programs employ a wide range of media and interaction modes, including computer-based presentation and interactions (Johnson, Ozogul, DiDonato, Reisslein, 2013; Johnson, Ozogul, Moreno, & Reisslein, 2013; Kester, Kirschner, & Van Merrienboer, 2005; Moreno, Reisslein, & Ozogul, 2009; Plant, et al., 2009; Reisslein, et al., 2005; Reisslein, Seeling, & Reisslein, 2006; Rosenberg,-Kima, et al., 2008, 2010; Van der Meij & de Jong; 2006) and hands-on activities (Reisslein, et al., 2013; Shyr, 2010; Shyr & Hsu, 2010; Yilmaz, et al., 2010).

Printed recruitment material, such as brochures, flyers, and postcards, that are handed to the students during the outreach activities or mailed directly to students' homes, or mailed to local schools for distribution in classrooms are often a component of engineering outreach campaigns. However, to our knowledge, the effectiveness of such brochures in improving students' perceptions of engineering or likelihood to pursue an engineering degree has not been examined. The goal of the current study was to initiate a rigorous research program to investigate the effectiveness of print brochures for increasing positive engineering perceptions in elementary school students.

Our paper is organized as follows. First, we present relevant theoretical background concerning the design of effective advertising and recruiting materials. Second, we describe the iterative design process of the brochure and perceptions survey instrument used in the current study. Third, we present results from tests examining the impact of the brochure on students' perceptions of engineering. We conclude with discussion of the results of our study including practical implications and plans for continuing the research on recruiting literature for engineering higher education institutions.

Hierarchy of Effects Model

The dominant theoretical model concerning the goals of advertising materials is the Hierarchy of Effects Model (Lavidge & Steiner, 1961). According to the model, advertising functions to move the target audience through six successive steps: 1) awareness of the product/brand; 2) knowledge of what it has to offer; 3) positive perceptions; 4) preference above other options; 5) desire to purchase; and 6) purchase. The model further asserts that there are three primary functions of advertising: 1) cognitive functions relating to ideas and information (steps 1 & 2); 2) affective functions relating to attitudes and feelings (steps 3 & 4); and 3) conative functions relating to consumer action (steps 5 & 6).

In development of engineering recruiting materials at a particular university, the resulting materials should therefore engender awareness of engineering and the university, provide knowledge of the offerings in the programs, promote favorable attitudes about engineering, and provide information which would set engineering as a field of study apart from other alternatives. If the fourth step is achieved through long-term, multi-faceted recruitment campaigns that include print-based materials, the hope is that pre-college students will then develop the desire to pursue engineering at that particular institution and follow through with enrollment (akin to purchase of a product).

Design of Brochure

The brochure used in this study was developed in collaboration with communications professionals in the Ira A. Fulton Schools of Engineering at Arizona State University. The design process was iterative in nature; the Engineering Communications department provided the research team with example recruitment brochures currently under development. Our team of psychologists, educators, and engineers provided feedback on the choice of photographs, verbal messages, and relative positioning/sizing of each of the elements, and the communications team responded with new versions for the next development iteration. For example, our research team noted that the initial photographs largely depicted white male students engaged in engineering study and research. We suggested that the communications team select photographs with a greater degree of diversity, to appeal to highly sought-after women and minorities in engineering disciplines.

With regard to the verbal messages, we selected a variety of stimulating stories about engineering projects and products in order to promote interest toward engineering study. For example: “Lifelens, a smartphone app to diagnose malaria, was developed by five graduate students” Each of these mini-stories about engineering projects/products were related to one of the ten engineering fields introduced by the brochure (each field represented as a program of study at ASU): 1) aerospace engineering, 2) civil engineering; 3) materials engineering; 4) biomedical engineering; 5) computer engineering; 6) electrical engineering; 7) mechanical engineering; 8) chemical engineering; 9) construction engineering; and 10) industrial engineering.

The research team also suggested that the brochure include a frame which provides information about the utility of engineering. Specifically, we recommended that the brochure familiarize students with the high demand for engineering graduates and the average starting salary for engineering disciplines. The development process of the brochure used in the study involved seven iterations within the research team and between our team and the communications team.

The final brochure was a two-page 11” x 17” glossy, colored pamphlet which was folded lengthwise and three times across (i.e., a total of six exterior frames and six interior frames). Figure 1 displays excerpts from the resulting brochure.

Figure 1. Excerpts from the brochure

Design and Method

Design

To examine the effectiveness of our developed brochure on promoting positive and reducing negative perceptions about engineering, we used a pretest-posttest design. Students completed a pretest survey instrument before viewing the brochure and completed the identical survey following exposure to the brochure. Differences in ratings at pretest and posttest were used to establish the effect of our brochure on students' perceptions about engineering.

Method

Participants. Participants included 100 4th grade students enrolled in a local elementary school in the Phoenix, Arizona area. Fifty-six percent (56%) of the students reported their ethnicity as Hispanic; 13% reported their ethnicity as 'Other'; 11% responded that they were Native American; 10% were White; 8% were African American; and 2% were Asian American.

Materials. The paper and pencil materials used in our study included the glossy, colored brochure described earlier, and the pre- and post-survey instrument. To establish the effect of our brochure on student perceptions toward engineering, we used an engineering perceptions survey that was adapted from Rosenberg-Kima, Plant, Doerr, and Baylor (2010). The current study employed much younger students, compared to the college students from this earlier study. Furthermore, 42% of our participants were English as a Second Language (ESL) learners; therefore, we modified the language used in the items to make them more appropriate for the linguistic capacity of the 4th grade students with a high proportion of ESL students. As an example, the survey item from Rosenberg-Kima et al. (2010) "The field of engineering is open to all people, regardless of gender" was altered to read "The field of engineering is open to all people, whether they are men or women." Early childhood education experts were used to verify the construct validity of the final survey used in our study (Aiken, 1997).

Identical versions of the 15-item survey were presented at pretest and posttest; the survey was subdivided into five subscales of perceptions toward engineering, with three items in each subscale: 1) gender stereotypes; 2) negative engineering stereotypes; 3) self-efficacy; 4) interest; and 5) utility.

For the three gender stereotype items, higher ratings indicated stronger rejection of gender stereotypes (e.g., “Women have the same talent for engineering as men”, Cronbach α = .74). Three items assessed negative stereotypes of engineering; higher ratings indicated acceptance of stereotypes (e.g., “Engineers are unpopular people”, α = .75).

For the self-efficacy, interest, and utility items, higher ratings indicated higher perceptions of self-efficacy, interest, and utility, respectively. The self-efficacy items measured students’ confidence in their own ability to study engineering and be engineers (e.g., “I would get good grades in engineering classes”, α = .76). Three items measured student interest in engineering (e.g., “I would be interested in working as an engineer”, α = .77). Finally, the utility subscale items asked students about their perceptions of the usefulness of engineering (e.g., “Studying engineering would prepare me well for many jobs”, α = .68). Individual ratings from the three items for each subscale of the survey instrument were averaged to obtain a mean gender stereotype, negative engineering stereotype, self-efficacy, interest, and utility rating.

The post-survey included an additional three items asking students specifically about their attitudes toward the brochure used in the study (α = 0.78). The three items were as follows: 1) “I liked the brochure about engineering”; 2) “I liked the descriptions of the engineering jobs” and 3) “I liked the pictures in the brochure”. Student ratings from these three items were averaged to obtain mean ‘Brochure Like’ ratings.

Each survey item was on a 5-point scale (1—strongly disagree to 5—strongly agree). Students responded by circling an emoticon that represented the level of agreement from 1—face with a strong frown (strongly disagree) to 5—face with a pronounced smile (strongly agree).

Procedure. Participants were tested in natural classroom sessions throughout a school day, in groups up to 25 students. At the beginning of each session, each student was given a unique experimental ID number and the pre-survey. Then, the students were instructed to write their ID number on the pre-survey and to complete all survey items. Once all students had completed the pre-survey, the pre-surveys were collected and one brochure was handed to each student. The students were instructed to inspect and read the brochures for seven minutes. After the seven minutes had elapsed, students were told to put away the brochures. Then, the post-surveys were distributed to the students and they were instructed to note their experimental ID on the post-survey and to complete all survey items. Then, post-surveys were collected for data analysis.

Results

To determine the effect of our engineering brochure on students' perceptions toward engineering, we conducted a series of paired-samples t-tests, with the average scores on each subscale of the engineering survey as dependent variable, and the time of testing (pre-survey or post-survey) as within-subjects variable. Students' average ratings on each of these subscales at pre- and post-survey are displayed in Table 1. Results indicated a significant impact of the brochure on students ratings of gender stereotypes, $t(99) = 4.55$, $p < .001$. The rejection of gender stereotypes was higher after viewing the brochure. Students also provided lower ratings of negative stereotypes of engineering after viewing the brochure, $t(99) = 3.57$, $p = .001$. Additionally, students had higher ratings of self-efficacy, $t(99) = 5.28$, $p < .001$, interest, $t(99) = 5.30$, $p < .001$, and utility, $t(99) = 6.47$, $p < .001$, at post-survey, compared to pre-survey ratings. Furthermore, ratings of brochure liking indicated very favorable student perceptions of the brochure used in the study ($M = 4.20$ [out of 5], $SD = 0.83$)

Table 1. Average Subscale Ratings of Perceptions Survey, by Pre- and Post-survey

	Pre-survey (N = 100) M (SD)	Post-survey (N = 100) M (SD)
Rejection of gender stereotypes	3.96 (0.71)	4.24 (0.77)
Negative stereotypes of engineering	2.60 (0.74)	2.38 (0.70)
Self-efficacy	3.24 (0.87)	3.72 (0.89)
Interest	3.39 (0.95)	3.89 (0.92)
Utility	3.45 (0.80)	3.95 (0.77)

Discussion

This paper reported on a study investigating the effectiveness of a newly designed engineering overview brochure intended to improve student perceptions about engineering. Following the Hierarchy of Effects Model of advertising (Lavidge & Steiner, 1961), we designed an engineering overview brochure with the following features: 1) attention-grabbing photographs depicting a diverse community of engineering learners; 2) stimulating stories about the products and projects of engineers; and 3) statements concerning the utility of engineering degrees. Differences in students' perceptions were established by comparing survey ratings on five dimensions of engineering perceptions at pre-survey and post-survey.

The results of the study indicated that the short exposure to the print brochure had a significant positive impact on student perceptions toward engineering. Comparing post-survey ratings to pre-survey, students had higher ratings of self-efficacy, interest, and utility of engineering, lower ratings of negative stereotypes of engineering, and higher rejection of gender stereotypes in engineering. The results suggest that high impact, but expensive outreach activities such as departmental open houses, summer camps, and mentorship programs may be easily supplemented using low-cost print recruiting materials, such as the brochure examined in this study. Furthermore, because prior research suggests that students' self-confidence in academic domains declines across grade levels (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002), the impact of such brochures may be more pronounced when implemented in lower grade levels, such as the 4th grade students considered in the current study. Overall, student ratings of their liking of the brochure was very high, indicating that these students felt very positively toward the design and messages used in our brochure. These positive perceptions of the brochure design likely contributed to the positive impact on students' perceptions toward engineering.

We suggest the following tactics for the design and application of effective engineering recruitment materials. First, we suggest that such materials should be designed using colorful engaging photographs of students from diverse backgrounds to reduce gender and ethnic stereotypes. Displaying a diverse set of students may also improve the perception of the brochure due to the similarity-attraction effect (Byrne & Nelson, 1965). Indeed, recent studies on the preferences of students for characteristics of pedagogical agents (e.g., Behrend & Thompson, 2011; Johnson, DiDonato, & Reisslein, 2013; Kim & Wei, 2011; Moreno & Flowerday, 2006; Ozogul, et al., 2013; Van der Meij, Van der Meij, & Harmsen, 2012) indicate that students prefer to learn from agents that are similar to the students in external characteristics, such as age, gender, and ethnicity. Also, the studies indicate that pedagogical agents with similar external characteristics as the students tend to improve the perceptions of the learning experience. By including photographs of students with a wide range of external characteristics, there is a greater chance that one of the displayed students is similar to the student reading the brochure, which may reinforce the message of the brochure through the similarity-attraction effect.

Second, including short descriptions of interesting engineering projects and products in a brochure may help increase interest in the engineering fields. Third, to make concrete the utility of the engineering degree, brochures should emphasize the high demand for qualified engineering graduates and the earning potential in engineering careers. Fourth, we advocate early intervention with recruitment materials to possibly avoid the development of low self-efficacy in academic domains related to engineering (i.e., science and mathematics, Jacobs, et al., 2002).

Limitations

The current study is limited in its examination of the effect of the brochure on a specific population (i.e., 4^{th} grade students in a southwestern state, largely Hispanic). A future study may investigate the effect of brochures using a variety of pre-college grade levels in various locations. Such a cross-sectional study may also lend greater support for our recommendation to use the recruiting materials with younger students. Additionally, the study did not include a control condition to make certain that positive perception changes occurred as a result of the brochure, and not simply the interactions with the research group from ASU and/or due to students deducing the purpose of the study and providing more positive perceptions at post-survey to meet the demand characteristics of the study (Rosenthal & Rosnow, 1991). A potential follow-up study may compare pre- and post-test survey responses with and without exposure to the brochure materials.

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