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Engineering perceptions of female and male K-12 students: effects of a multimedia overview on elementary, middle-, and high-school students

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Computer-based multimedia presentations employing animated agents (avatars) can positively impact perceptions about engineering; the current research advances our understanding of this effect to pre-college populations, the main target for engineering outreach. The study examines the effectiveness of a brief computer-based intervention with animated agents in improving perceptions about engineering. Five hundred sixty-five elementary, middle-, and high-school students in the southwestern USA viewed a short computer-based multimedia overview of four engineering disciplines (electrical, chemical, biomedical, and environmental) with embedded animated agents. Students completed identical surveys measuring five subscales of engineering perceptions immediately before and after the intervention. Analyses of pre- and post-surveys demonstrated that the computer presentation significantly improved perceptions for each student group, and that effects were stronger for elementary school students, compared to middle- and high-school students.

Keywords: avatar; engineering perceptions; engineering stereotypes; multimedia programme; pre-college K-12 students; overview of engineering fields

1. Introduction

Due to the increasing demand for a skilled engineering workforce, there is a serious need to find best practices in recruitment and retention of engineering majors (Becker 2010; Prieto et al. 2009). Of particular importance is developing effective recruiting tools to reach female and minority K-12 students, as the engineering workforce remains dominated by white males (CPST 2004). Although some universities and organisations have developed large outreach and recruiting programmes to draw students to engineering programmes of study (Adams et al. 2011; Carberry and Church 2009; Delaine et al. 2010; Fantz, Siller, and DeMiranda 2011; Innes et al. 2012; Little and Leon de la Barra 2009), there is still a need for low-cost, short-term interventions which improve student engineering perceptions.

There is considerable evidence showing that people treat computers as social entities (Reeves and Nass 1996). The social element of multimedia computer programmes can be enhanced by using animated agents (avatars). Students with little or no understanding of engineering topics may benefit from viewing animated agents that competently introduce the engineering domain (Heidig and Clarebot 2011; Moreno, Reisslein, and Ozogul 2010). Perceptions of engineering

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can be promoted through these competent social models. As a result, students may have reduced feelings of gender stereotypes in engineering, feel greater confidence in their own competence in the domain (i.e. self-efficacy; Bandura 1997), and have more positive attitudes (e.g. feelings of usefulness of engineering) and increased interest in engineering. Recent studies found positive effects of a multimedia engineering overview module with animated agents on the engineering stereotypes and perceptions of college students (Rosenberg-Kima et al. 2008, 2010) and middle-school students in grades 6–8 (Plant et al. 2009). Complementary to the existing studies, the current study investigated the influence of a multimedia engineering overview with animated agents on the engineering stereotypes and perceptions of elementary schools students in grades 3–5, middle-school students in grades 6–8, and high-school students in grades 9–12.

1.1. *Student perceptions of engineering*

There is ample evidence that students have preconceived notions of engineering as a discipline and about the characteristics of engineers (Brawner et al. 2012; Tully and Jacobs 2010). For instance, although there are no systematic studies of children's engineering gender stereotypes, evidence from draw-an-engineer studies indicates that young students envision engineers as male (Capobianco et al. 2011; Fralick et al. 2009; Karatas, Micklos, and Bodner 2011; Knight and Cunningham 2004). If, as this work suggests, males and females stereotype engineering as a masculine domain, subsequent engineering-related outcomes may be affected. For example, girls and women who endorse math- and science-related stereotypes (i.e. believe that boys and men are better at math and science than girls and women) report and achieve lower grades in these fields (Chatard, Guimond, and Selimbegovic 2007; Guimond and Roussel 2001; Nosek et al. 2009). The endorsement of engineering gender stereotypes may similarly affect girls' and women's desire for and success in engineering.

Other work has shown that many students believe that the engineering profession is associated with fixing or building things, that engineering is largely physical labour, and that engineering is boring or 'nerdy' (Aswad, Vidican, and Samulewicz 2011; Cunningham, Lachapelle, and Lindgren-Streicher 2005; Gibbons et al. 2004; Oware, Capobianco, and Diefes-Dux 2007; Powell, Dainty, and Bagilhole 2012). Similar to gender stereotypes, these preconceived notions of the engineering profession likely impact students', particularly young girls', feelings of self-efficacy towards engineering which can ultimately translate to lower self-confidence in college (Meyers et al. 2010). In fact, even when undergraduate female students have equivalent preparation and grades in preliminary courses, their self-reported confidence in academic preparation tends to be lower and their anxiety about coursework tends to be higher (Besterfield-Sacre et al. 2001; Borrego et al. 2005; Else-Quest, Hyde, and Linn 2010; Felder et al. 1995).

According to the expectancy-value theory of achievement motivation (Wigfield and Eccles 2000), stereotypes contribute to student's likelihood in choosing a field of study, persistence within that field, and enthusiasm in studying through a diverse set of attitudes about oneself and about academic tasks. A critical self-perception within the model is self-efficacy, that is, a student's self-assessment of his or her current competency level (Wigfield and Eccles 2000). All other factors being equal, the higher a student's self-efficacy, the more likely s/he will pursue a particular domain with greater motivation to succeed. Two essential achievement value constructs, which also positively contribute to a student's decision to pursue an academic domain, are interest value and utility value. Interest value is the level of enjoyment gained from engaging in a particular activity or studying a domain, and utility value is defined as how well 'a task fits into an individual's future plans' (Wigfield and Eccles 2000). The current investigation thus includes measures of student self-efficacy, utility, and interest in engineering.

Early intervention may be critical to alter females' perceptions about engineering. The Educational Testing Service reported that confidence in mathematics was roughly equivalent between boys and girls in the third grade, but by the eleventh grade, the gap in mathematics confidence had diverged; 48% of 11th-grade girls and 60% of 11th-grade boys thought they were good in math (Dossey et al. 1988). More recent reports and statistics indicate similar drops in math and science interest and confidence as students progress from elementary to high school and college (Else-Quest, Hyde, and Linn 2010; NCES 2004; NSF 2006). Harter (1999) has suggested that students' self-efficacy in academic tasks develops over the course of the students' experiences with school activities. Empirical work has shown that older students have a more differentiated view of competence in various domains (Eccles et al. 1993) and that, in general, self-efficacy in academic domains decreases from grade 1 to 12 (Jacobs et al. 2002). As students more strongly associate themselves with particular subjects in school and dissociate from others (e.g. mathematics), they may be less influenced by new information about a discipline such as engineering. One of the goals of this study was to determine whether a computer-based outreach module with animated agents would impact changes in engineering perceptions differentially for elementary, middle-, and high-school students.

1.2. *Design and hypotheses*

The present study was conducted with elementary (3rd–5th grade), middle- (6th–8th grade), and high-school (9th–12th grade) students in the USA to examine two research questions relating to computer-based outreach interventions across the K-12 student population. First, the effectiveness of a short computer-based outreach intervention with animated agents was examined with a pre-survey–post-survey design that measured changes in student perceptions towards engineering from watching the multimedia engineering overview. Second, pre- to post-survey changes in student perceptions were analysed across the student groups to determine whether such interventions have greater impact at earlier ages.

Because previous research (Plant et al. 2009; Rosenberg-Kima et al. 2008, 2010) shows that a multimedia module with embedded animated agents is effective in altering middle-school student and college student engineering perceptions, we expected that the computer-based outreach multimedia module would lead to positive changes in the engineering perceptions of students in elementary through high school (Hypothesis 1). Specifically, we predicted that after viewing the multimedia module, students would be more likely to reject gender stereotypes and have lower ratings of stereotypes of the engineering profession. Also, after viewing the computer module, student feelings of self-efficacy, utility, and interest in engineering would be higher.

We also hypothesised that older students (i.e. high school) would have more developed and thus more static perceptions of engineering (Dossey et al. 1988; Harter 1999). Therefore, we predicted pre- to post-survey changes in gender stereotypes, engineering profession stereotypes, self-efficacy, utility, and interest to be larger for younger (i.e. elementary school) students compared to older (i.e. high-school) students (Hypothesis 2).

2. Method

2.1. *Participants and design*

Participants included 565 elementary, middle-, and high-school students from urban local schools in the southwestern USA. Demographic information on the participants is reported in Table 1. A limitation of this study is that characteristics of the families of these students, such as income level, profession, and education level of the parents, are not included in the student characterisation.

Table 1. Participant demographics, by student group.

	Total	Gender		Age	Ethnicity					
	N	Male	Female	*M* (SD)	Hispanic	Caucasian	African American	Native American	Asian American	Other
Elementary school grades 3–5	223	108	115	9.95 (0.86)	80 (35.9%)	53 (23.8%)	26 (11.7%)	15 (6.7%)	6 (2.7%)	43 (19.3%)
Middle-school grades 6–8	200	99	101	11.9 (0.90)	49 (24.5%)	98 (49.0%)	13 (6.5%)	4 (2.0%)	9 (4.5%)	27 (13.5%)
High-school grades 9–12	142	79	63	15.5 (1.49)	59 (41.5%)	35 (24.6%)	15 (10.6%)	10 (7.0%)	5 (3.5%)	18 (12.7%)

2.2. *Materials and apparatus*

2.2.1. *Computerised materials*

The computerised materials consisted of a multimedia computer program that included four phases: (1) a demographic questionnaire; (2) an introductory video that familiarised students with the field of engineering, noting the wide range of engineering disciplines and highlighting that the work of engineers relates to almost everything that humans eat, drink, wear, touch, see, hear, and smell daily; (3) four short videos that informed students about four engineering disciplines; and (4) a summary video that concluded the overview of engineering.

During phase (3), animated agents (avatars) with pre-recorded human voices narrated a script and images were displayed concurrently to illustrate engineering processes and products. More specifically, phase (3) displayed four videos introducing students to four disciplines of engineering: electrical, chemical, biomedical, and environmental engineering. The videos briefly explained what problems engineers of each discipline address and highlighted products developed by these engineers, such as cell phones developed by electrical engineers. The images and narration used in videos were crafted to positively influence students' interest in and perceptions of the utility of engineering by focusing on the stimulating functions of engineering, such as inventing, problem solving, improving society, and on 'cool' engineering products, such as cell phones, amusement park rides, and sports cars. The animated agents were expected to positively influence the self-efficacy of the students through modelling competence in engineering disciplines. The presentation order of the engineering disciplines was fixed, and each was presented by one of four animated agents (order of agents was randomised): a young female agent, a young male agent, an old female agent, and an old male agent (Figure 1). The animated agents pointed to images in the videos through deictic gestures, for example, pointing with arms and fingers.

The design of the animated agents was inspired by similar avatars found in games that are popular among pre-college students. More specifically, the animated agents were 3D computer agents created with Autodesk 3D Studio Max 5, a software for building, animating, and rendering 3D models and characters. The narration voice files were applied to the agents using the Ventriloquist program, which uses a collection of 12 phonemes to animate the agent's mouth and facial expressions in correlation to recorded speech. Additional facial expressions of eyebrow motions, eye movements, and head nods as well as animated body and hand movement were added. All of these animated movements were cued within 3D Studio Max to the speech of the agents. Completed agent animations were rendered by 3D Studio Max as video files which were imported into Adobe After Effects CS2.

The computer-based engineering overview module used in the study was developed using Adobe Flash CS4 software, an authoring tool for creating web-based and standalone multimedia

Figure 1. Still image samples of the four animated agents used in the multimedia overview. Left to right: young female, young male, old female, old male.

programmes. Electronic log files were produced by the programme, including participant demographic responses. The equipment consisted of a set of laptop computer systems, each with a screen size 15.6 inches and a resolution of 1680 × 1050 pixels, and headphones.

2.2.2. *Engineering perceptions survey*

Paper and pencil materials consisted of a pre-survey and a post-survey of student engineering perceptions. The pre- and post-surveys were identical and included 19 modified items covering five subscales of engineering perceptions from Rosenberg-Kima et al. (2010), which are similar to subscales developed and validated by Hirsch et al. (2003). Because the current study involved significantly younger students than the college students in Rosenberg-Kima et al. (2010), the wording of items was changed to reflect their developmental level. For example, the original item ‘The field of engineering is open to all people, regardless of gender’ was changed to ‘The field of engineering is open to all people, whether they are men or women.’ The construct validity of the resulting items was verified with the judgment of early childhood education experts (Aiken 1997). The survey subscales and individual items are presented in the appendix.

Four items asked students about gender stereotypes in engineering, with higher ratings indicating stronger rejection of such stereotypes (Cronbach $\alpha = .74$, e.g. ‘Women have the same talent for engineering as men’). Three items assessed students’ stereotypes of the engineering profession, with higher ratings indicating acceptance of engineering stereotypes ($\alpha = .41$, e.g. ‘Engineers are unpopular people’). We concede that the reliability for the engineering profession stereotypes subscale is low, thus the conclusions from analyses on these items are made with caution.

Three items measured student self-efficacy in engineering ($\alpha = .67$, e.g. ‘I would get good grades in engineering classes’). Five items measured student interest in engineering ($\alpha = .82$, e.g. ‘I would be interested in working as an engineer’). Four items asked students their perceptions of the utility of engineering ($\alpha = .67$, e.g. ‘Studying engineering would prepare me well for many jobs’).

All of the survey items were on a 5-point scale ranging from 1 – strongly disagree to 5 – strongly agree. Students responded to each item 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).

2.3. *Procedure*

Participants were assessed during their regular class meetings, in groups of 10–31 students at a time. At the beginning of the session, each participant was provided with a laptop, headphones, and the pre-survey. The subject identification number was written on the pre-survey. The researcher instructed students on how to independently complete the pre-survey. When the students indicated they understood the pre-survey scale, they provided their responses.[1] After all students finished the pre-survey, the researcher collected the pre-surveys and instructed students to begin the computer-based module by entering their subject identification number and demographics. They were then instructed to put on their headphones and work independently on all sections of the module. The average time for students to complete the computerised overview programme was 12.2 minutes (SD = 3.8 minutes). Once the computer-based session was over, each participant was given the post-survey and asked to independently respond to the items as he/she felt after viewing the module. The researcher then collected all the laptops and the post-surveys for data entry and analysis.

3. Results

3.1. *Overall pre-post perceptions comparison*

Table 2 shows pre-survey and post-survey means and standard deviations for each student group (elementary, middle, and high school) on the five subscales of engineering perceptions (gender stereotypes, engineering profession stereotypes, self-efficacy, utility, and interest). For each student group, a series of paired-samples *t*-tests were run to compare student ratings on each of the five subscales at pre-survey and post-survey. Given the number of tests for each student group, we applied the Bonferroni correction procedure (Miller 1981) in modifying the alpha level for significance in these tests. The alpha level was set to .01 (.05/5 tests). Inferential statistics for these tests are included in Table 2.

All students had significantly higher rejection of gender stereotypes as well as significantly higher ratings of self-efficacy and utility at post-survey than at pre-survey. The elementary and middle-school students also had significantly higher interest ratings post-survey than at pre-survey. Effect sizes for these subscales were medium for the elementary school students (.44–.71), but small for middle- (.25–.42) and high-school (.19–.32) students. For elementary and middle-school students, the analyses also indicated significantly lower ratings of engineering profession stereotypes (with small effect size, .22–.28) at post-survey, compared to pre-survey ratings. However, given the low reliability of the engineering profession stereotypes subscale, we suggest caution in concluding that the module had a significant impact in reducing negative stereotypes about the engineering profession.

3.2. *Student gender comparison*

In order to investigate potential differences between male and female students' initial perceptions of engineering, a series of independent samples *t*-tests were conducted comparing male and female students on their pre-survey ratings for each subscale (see Table 3 for descriptive and inferential statistics). To account for the number of tests run for each student group, the Bonferroni correction procedure was applied, resulting in an alpha level of .01 (.05/5 tests). Results indicated that, at pre-survey, elementary male students did not significantly differ from their female counterparts

Table 2. Pre- and post-survey means and standard deviations for five subscales of engineering perceptions survey, by student group.

Student group perception subscale			
Elementary school ($N = 223$)			
	Pre-survey M (SD)	Post-survey M (SD)	Inferential statistics $t(222)$, p^a, Cohen's d^b
Rejection of gender stereotypes	4.14 (0.71)	4.50 (0.64)	8.81, <.001, .53
Eng. profession stereotypes	2.42 (0.69)	2.25 (0.83)	3.35, .001, .22
Self-efficacy	3.33 (0.80)	3.91 (0.84)	10.57, <.001, .71
Interest	3.78 (0.84)	4.15 (0.86)	7.09, <.001, .44
Utility	3.60 (0.76)	4.02 (0.73)	8.45, <.001, .56
Middle school ($N = 200$)			
	Pre-survey M (SD)	Post-survey M (SD)	Inferential statistics $t(199)$, p, Cohen's d
Rejection of gender stereotypes	4.46 (0.65)	4.70 (0.49)	6.78, <.001, .42
Eng. profession stereotypes	2.13 (0.70)	1.94 (0.64)	5.02, <.001, .28
Self-efficacy	3.38 (0.89)	3.60 (0.88)	4.95, <.001, .25
Interest	3.55 (0.94)	3.79 (0.85)	5.94, <.001, .27
Utility	3.71 (0.74)	3.91 (0.72)	4.93, <.001, .27
High school ($N = 142$)			
	Pre-survey M (SD)	Post-survey M (SD)	Inferential statistics $t(141)$, p, Cohen's d
Rejection of gender stereotypes	4.46 (0.57)	4.60 (0.52)	4.09, <.001, .26
Eng. profession stereotypes	2.43 (0.64)	2.31 (0.82)	2.29, .02
Self-efficacy	3.27 (0.84)	3.53 (0.79)	4.95, <.001, .32
Interest	3.46 (0.89)	3.57 (0.95)	2.30, .02
Utility	3.72 (0.67)	3.85 (0.73)	3.34, <.001, .19

[a]Bonferroni correction results in alpha level of .01 for test of significant results.
[b]Effect sizes reported for significant comparisons.

on any of the perception subscales. For middle-school students, males had significantly higher ratings (with large effect sizes, .85–.91) of self-efficacy, utility, and interest, whereas females had higher rejection (with a small effect size of .44) of gender stereotypes. For high-school students, results indicated that male students had significantly higher ratings of self-efficacy, utility, and interest than female students (with medium to large effect sizes, .61–.91).

Change scores for each subscale on the engineering perceptions survey were computed (e.g. interest change = post-survey interest - pre-survey interest) to investigate differences among male and female students' inclinations to alter perceptions of engineering. A series of independent samples tests were conducted to compare males and females on the change scores. Results revealed no significant differences between change scores for male and female students in any of the student groups. For instance, there was no significant difference between the pre- to post-survey changes of female elementary school students compared to male elementary school students. Thus, the engineering perceptions significantly improved for both genders in each student group and the improvement was of equivalent magnitude for both males and females.

3.3. *Student group comparison*

Change scores (post-survey – pre-survey) for each subscale on the engineering perceptions survey (Table 2) were computed to compare the engineering perception changes of the different student

Table 3. Pre-survey means and standard deviations for five subscales of engineering perceptions survey, by student gender.

Elementary school (N = 223)			
	Male (N = 108) M (SD)	Female (N = 115) M (SD)	Gender comparison $t(221)$, p[a], Cohen's d
Rejection of gender stereotypes	4.05 (0.80)	4.22 (0.61)	1.79, .08
Eng. profession stereotypes	2.41 (0.71)	2.43 (0.68)	0.23, .82
Self-efficacy	3.47 (0.82)	3.21 (0.76)	2.41, .02
Interest	3.86 (0.83)	3.71 (0.85)	1.32, .19
Utility	3.69 (0.83)	3.51 (0.68)	1.72, .09
Middle school (N = 200)			
	Male (N = 99) M (SD)	Female (N = 101) M (SD)	Gender comparison $t(221)$, p, Cohen's d
Rejection of gender stereotypes	4.32 (0.73)	4.60 (0.53)	3.13, <.005, .44
Eng. profession stereotypes	2.05 (0.63)	2.21 (0.75)	1.61, .11
Self-efficacy	3.75 (0.76)	3.03 (0.86)	6.27, <.001, .89
Interest	3.92 (0.85)	3.18 (0.89)	6.01, <.001, .85
Utility	4.02 (0.62)	3.41 (0.72)	6.42, <.001, .91
High school (N = 142)			
	Male (N = 79) M (SD)	Female (N = 63) M (SD)	Gender comparison $t(221)$, p, Cohen's d
Rejection of gender stereotypes	4.40 (0.58)	4.54 (0.56)	1.45, .15
Eng. profession stereotypes	2.38 (0.66)	2.49 (0.62)	0.99, .33
Self-efficacy	3.49 (0.74)	2.99 (0.89)	3.65, <.001, .61
Interest	3.75 (0.71)	3.09 (0.95)	4.74, <.001, .79
Utility	3.97 (0.58)	3.41 (0.65)	5.46, <.001, .91

[a]Bonferroni correction results in alpha level of .01 for test of significant results.

groups. A series of one-way analysis of variances were conducted using the change scores for each subscale as the dependent variable and student group (elementary, middle, high) as the independent variable. The alpha level for these tests was set to $\alpha = .01$ (.05/5 for Bonferroni correction; Miller 1981). There was a significant difference among student groups in change scores for gender stereotypes, $F(2, 562) = 7.46, p < .001$; self-efficacy, $F(2, 562) = 16.76$, $p < .001$; utility, $F(2, 562) = 11.32$, $p < .001$; and interest, $F(2, 562) = 6.50, p < .005$. The analysis did not indicate a significant difference among student groups in changes associated with engineering profession stereotypes, $F(2, 562) = 0.59, p = .55$. Follow-up Turkey comparisons indicated that, compared to high-school students, elementary students had significantly higher change scores in gender stereotypes ($p < .001$), self-efficacy ($p < .001$), utility ($p < .001$), and interest ($p < .001$). Compared to middle-school students, elementary students also had significantly higher change scores in self-efficacy ($p < .001$) and utility ratings ($p < .001$). Middle-school change scores did not differ significantly from high-school change scores for any of the subscales.

4. Discussion

4.1. *Engineering perception comparisons*

The results of this study provide evidence that a computer-based overview of engineering fields leads to more positive perceptions of engineering for K-12 students (Hypothesis 1). Elementary, middle-, and high-school students had significantly higher rejection of gender stereotypes as well as significantly more positive feelings of self-efficacy and utility after having viewed the computer-based multimedia presentation. Furthermore, elementary and middle-school students had significantly lower engineering profession stereotypes and reported significantly higher interest in engineering. These results indicated that a multimedia module with embedded animated agents presenting an overview of the engineering field has a positive effect on the engineering perceptions of the K-12 student population ranging from elementary school students in grades 3–5 through middle-school students in grades 6–8 and high-school students in grades 9–12. Similar positive effects have previously been demonstrated for college students (Rosenberg-Kima et al. 2008, Experiment 1) and middle-school students (Plant et al. 2009).

The student group comparison supported our hypothesis that older students' perceptions of engineering are more static than younger students (Hypothesis 2). Change scores in gender stereotypes, self-efficacy, utility, and interest were significantly higher for elementary students than for the high-school students. Furthermore, the elementary students had significantly higher change scores for self-efficacy and utility compared to the middle-school students. Generally, as students mature through the levels of K-12 education, they form differentiated perceptions of self-efficacy towards academic domains (Eccles et al. 1993; Harter 1999; Jacobs et al. 2002). These perceptions are based on a more extensive set of experiences with school activities in older students which may make it more difficult to alter perceptions with an outreach intervention. Overall, these engineering perception results across student groups indicate that early intervention (Clark and Andrews 2010; Reisslein et al. 2013) is critical to achieve greater shifts in perceptions of engineering disciplines.

This early intervention approach may be even more crucial when attempting to foster female students' confidence and interest in engineering. A number of studies have reported diverging interest and confidence perceptions towards math and science between males and females with increasing age (Akpinar et al. 2009; Dossey et al. 1988; Else-Quest, Hyde, and Linn 2010; NCES 2004; NSF 2006). Our pre-survey results in Table 3 demonstrate similar trends across the student groups during K-12 education for perceptions towards engineering. At the elementary school level, the pre-existing engineering perceptions of male and female students did not differ significantly. On the other hand, male middle- and high-school students had more positive pre-existing engineering perceptions than their female counterparts on three subscales (self-efficacy, utility, and interest), with medium to large effect sizes ranging from .61 to .91. In order to expand and diversify the supply of pre-college students who are enthusiastic to study and practice engineering, it is essential to find methods that prevent young students from developing negative stereotypes of or low self-efficacy in engineering. Computer-based multimedia outreach interventions with animated agents may be used regularly to maintain steady feelings of potential competence in and interest towards engineering fields.

Taken together, the comparative analysis of the three student groups supports widespread utilisation of outreach efforts at the elementary school level. Multimedia programmes with embedded animated agents show promise in efforts to influence young students' perceptions of engineering and appear more effective in younger populations (i.e. elementary school) compared to older students. Not only do these multimedia programmes appear to be associated with significant positive changes in student perceptions, such computer programmes can be developed with relative ease and widely disseminated to the K-12 population using modern technology. Such multimedia presentations can be hosted on web servers which students, teachers, and administrators can access in class or at home.

4.2. *Limitations and future research directions*

The primary limitation of the current investigation is the lack of a control group to make definitive conclusions that the computer-based module was the singular source of perception change for the students. It is possible that administration of the same post-survey measure immediately following the intervention can cue the students to the expectations of results, resulting in demand characteristics in which the students respond in ways to meet these expectations (Rosenthal and Rosnow 1991, 115). Subsequent investigation of the impact of such materials may include a control group which does not view the computer-based module and possibly another control group which views the same videos without the embedded animated agents.

A second limitation of our study was the low reliability of the engineering stereotypes subscale. To address this issue, these items can be further refined and tested.

Furthermore, it would be of interest to investigate the effects of regular periodic exposure to multimedia overview presentations on engineering with both immediate and delayed evaluation components. Such investigations could give insights into how the frequency of exposure to engineering overviews influences the development of engineering perceptions.

5. Conclusions

In conclusion, short computer-based multimedia programmes with embedded animated agents can be used in school-based outreach efforts to bring about significant immediate positive effects on K-12 students' perceptions of engineering disciplines. Such materials have the potential for widespread distribution to students to improve engineering self-efficacy and perceptions of the value of an engineering degree in K-12 student populations. Our results indicate that early exposure to such engineering overviews, that is, as early as in grades 3–5, has a more pronounced positive impact on engineering perceptions than exposure at higher grade levels. Our pre-survey results (Table 3) contribute to the empirical knowledge base of pre-existing perceptions of engineering in the US K-12 student population by comprehensively covering elementary school grades 3–5 through high-school grades 9–12. Such comprehensive investigation of US K-12 student perceptions had previously only been reported for math and science (Dossey et al. 1988; Else-Quest, Hyde, and Linn 2010). The pre-existing perceptions results indicate that males and females do not yet differ in their engineering perceptions in elementary school grades 3–5, while females have significantly lower perceptions than males in the middle- and high-school grades 6–12. These results further underscore the need for early exposure to engineering so as to avoid or mitigate girls' negative perceptions of engineering (Hughes 2002; Thaler and Zorn 2010), which can profoundly influence their interest in pursuing engineering careers (Betz and Hacket 1983).

Note

1. For the elementary students, the researcher read each item of the survey aloud.

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Appendix. Engineering perceptions survey subscales and items

Perception subscale	Survey item
Rejection of gender stereotypes	Women can succeed in engineering
	Women have the same talent for engineering as men
	Women can do as well as men in engineering
	The field of engineering is open to all people, whether they are men or women
Engineering profession stereotypes	Engineers are very busy at their job and do not have free time
	Engineers are unpopular people
	Engineers are boring people
Self-efficacy	I could succeed in engineering
	I believe I have talent for engineering
	I would get good grades in engineering classes
Interest	I would like to learn more about engineering
	I would be interested in working as an engineer
	I would be interested in studying engineering at a university
	I would like to learn about what engineers do at work
	I would like to learn about jobs in engineering
Utility	Being an engineer would be good for me
	I could get a good job if I studied engineering
	Studying engineering would prepare me well for many jobs
	I could make a lot of money if I became an engineer

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