AC 2010-127: GAINS IN KNOWLEDGE AND PERCEPTION OF ENGINEERING AFTER PARTICIPATION IN AN ENGINEERING DESIGN WEB-EXPERIENCE ARE GENDER-DEPENDENT

Kimberly Edginton Bigelow, University of Dayton

Kimberly Edginton Bigelow is an assistant professor in the Department of Mechanical and Aerospace Engineering at the University of Dayton. Her focus area is biomechanical engineering. Kim teaches the freshmen engineering design experience and is involved in a number of K-12 engineering outreach activities.

Gail Wheatley, Edheads

Gail Wheatley is the founder and President of Edheads (www.edheads.org), a website featuring interactive educational activities focused on science and technology. She has 23 years experience in informal science education centers such as museums and nature centers. She has a passion for making education fun and engaging.

David Tomasko, The Ohio State University

David Tomasko is Associate Dean for Undergraduate Education and Student Services in the College of Engineering at the Ohio State University. He previously served as Director of the Honors Collegium.

Gains in Knowledge and Perception of Engineering after Participation in an Engineering Design Web-Experience are Gender-Dependent

Abstract

Web-based activities have the potential to teach engineering in both formal and informal science education settings, maximizing outreach efforts. To date, many activities available on the internet teach about engineering, but few allow students to truly “do” engineering. This project utilized web animation and interaction in the design of a web-based experience focused on engineering design. In this activity, targeted toward middle school students, users played the role of engineer and engaged in the process of designing a cell phone for the older adult market. It was hoped that this web-based activity would increase participant understanding of what engineering is and the steps of the engineering design process, while also encouraging students to consider engineering-related careers. An additional aim of this study was to determine whether the web-based application and the object of design (a cell phone) would appeal to female students as much as it would to male students.

To test this, 162 middle-school students participated in the web-experience. Summative measures were taken pre- and post- activity using an on-line web-based survey to test their knowledge of engineering design and the engineering design process. The post-survey also asked additional questions to determine students’ perceptions of engineering and also perceptions of the web activity. Data were analyzed for the central tendencies of each question, item and scale means, and cross tabulated to identify statistically significant differences between the responses of male and female students.

Prior to the web-based experience female students had a higher base-line knowledge of what engineering is than male students ($p = 0.026$), however after participation in the activity there were no statistically significant gender-based differences. The activity did increase understanding of engineering in the group as a whole, with a mean increase from 5.12 out of 10 correct responses on the pre-test to 7.10 out of 10 ($p = 0.000$). Regarding the web-experience, female students tended to express better perceptions of the elements of the activity, but these differences were not statistically significant. Despite the activity, female students exhibited less positive perceptions of engineering and engineering as a career than male students. They were less likely to feel they could become an engineer if they wanted to (0.005), to see themselves in an engineering-related career ($p < 0.000$), and to see themselves as an engineer ($p <0.000$) compared to their male counterparts.

These results suggest that female middle-school students have a better base knowledge of what engineering is than male students, and that a web-based engineering experience can improve understanding in both genders. Both female and male students perceived the website activity positively, which promotes future use of this educational means. Future work is needed to determine how similar activities can be altered to better address the disparity in perceptions of engineering as a career between genders.

Introduction

In the 2008 National Academy of Engineering's report, *Changing the Conversation*, the material presented focused on the concern that many Americans do not truly understand what engineering is.[1] As such, this has led to concern over ability to sustain the U.S. capacity for technological innovation, ability to attract young people to careers in engineering, and ability to improve technological literacy.[1] Though efforts to promote engineering have been numerous and wide-spread, with hundreds of millions of dollars spent annually on increasing understanding of engineering, the impact has been minimal.[2,3] Research has shown that despite these efforts, K-12 students, and teachers, continue to have a poor understanding of what engineers do.[3,4] In fact, public opinion indicates that it is commonly believed that engineers do not work on problems that address societal and community concerns.[5] There is a need, therefore, to find innovative ways to effectively promote engineering, especially in grades K-12, such that students are more knowledgeable about engineering, and as such have better perceptions of engineering as a possible career choice.

One possible mode of delivery of such an effort is through web-based activities and experiences. This is advantageous as it allows for a means of education through both formal and informal science settings. The National Science Foundation has recognized this need to reach students not only inside the classroom, but outside as well, through their Informal Science Education (ISE) program.[6] Though web-based activities concentrated on engineering are currently available, the majority are limited by the scope of what they offer. A review of several popular engineering-based websites, such as http://www.girlsgotech.org and www.engineergirl.org, demonstrate the prominent use of text and photos to educate students about engineering or the engineering design process – without allowing the user the ability to freely design.[7,8] Bloom's Taxonomy suggests the importance of involving the student as actively and as in-depth as possible for higher-level learning to occur.[9] Allowing students to be actively involved in the engineering process seems particularly important as, despite continual efforts to promote engineering, perception of what engineers do remains largely unchanged.[3,4] The ability, enabled by the internet, for students to take on the persona of an engineer and be actively engaged in the design process may be an important step in changing perspectives.

A few websites do allow users to work through design activities. For example, in http://www.tryengineering.org/play.php students can design objects such as a bionic arm and a parachute.[10] However, these problems are well-defined, often involving only one or two variables, and removing much of the testing process from the user's control. It was felt by the research team that the development of a new Flash-based animation system where the user became an engineer and actively participated in all steps of the design process was necessary. Utilizing the engineering design process laid forth in Dym and Little's *Engineering Design: A Project-Based Introduction*, it was important that users did not just design – but that they conducted background research to better define the problem, designed based on the revised problem statement, tested the design using appropriate tools and methods, had the opportunity to revisit the design stage, determined when the design was acceptable, and then received feedback about the product's success or failure (with the option to go back and redesign again).[11] To maximize student learning and overcome limitations of currently available websites, it was also important that the developed website would be more in-depth, enable multiple types of learning, allow users to make mistakes, require active thinking, and mirror real world engineering tasks, all of which are elements that have been identified as providing users an engaging real-life simulation of engineering which can result in a "I can do this"-realization.

Edheads (www.edheads.org), the lead behind this project, is well known for its interactive web-experiences. A number of experiences are available, exploring different types of fields; however, there had not previously been an experience focused on engineering. As one of its most successful experiences, Edheads has designed and implemented a Virtual Knee Surgery activity where users take on the persona of a surgeon and participate step-by-step through the process required for knee surgery. Launched in 2004, the activity has won many awards, including the Macromedia Flash Forward Award for Educational Design, as well as having over 16 million unique users. This activity, however, followed a very linear nature. This step-by-step process was deemed inappropriate to demonstrate the open-ended nature and iterative nature of engineering. It was also identified as a possible turn-off to girls, as Agosto found that girls prefer 'flexible' web activities that allow personal decision making and choices regarding when the end of the activity had been reached.[12] Ensuring that the designed web-based experience was inclusive to females was an important goal of this project, as increasing the potential interest of careers in STEM in this target population has received national attention.

The percentage of women in undergraduate engineering courses has hovered around 20 percent for over 15 years, and in 2007 only 18.1% of engineering degrees were awarded to women.[13] If, as according to *Changing the Conversation*, an important goal is to attract young people to careers in engineering, it is important that a particular effort be aimed at increasing interest in females. It is believed that part of the problem is that society – as experienced in education through parents, the media, and educators – tends to reinforce traditional assumptions about the capabilities, interests, and career options for girls and women, steering them away from STEM classes, majors, and careers.[14-19] Harvey Mudd College has suggested one possible approach to overcoming this obstacle is to emphasize connections between engineering and social sciences and humanities, real world applications and interactive teamwork.[20] The open-ended nature of web-based design allows for this inclusive environment to be created within the web-based activity, catering to females. An associated concern, however, was whether the media of delivery might still be more favorable to males, as video gaming is traditionally considered a more male-dominated activity.

This project thus sought to design an interactive web-based experience where the user became an engineer and interactively participated in the engineering design process – doing design. To cater to girls' desires to connect engineering and societal needs, as well as design interests of teenagers, the chosen activity was to design a cell phone that met the needs of senior citizens. Research was then conducted pre- and post- experience to determine whether students' knowledge of engineering and perceptions and interests of engineering changed, and whether these changes were gender-dependent. It was hoped that this web-based activity would increase participant understanding of what engineering is and the steps of the engineering design process, while also encouraging students to consider engineering-related careers.

Design of the Web-based Experience

The completed version of the web-based experience *Design a Cell Phone* is now freely available at www.edheads.org/activities/eng_cell/.[21] It was designed for a target audience of Grades 6 -8. During preliminary stages of website design, feedback was sought from both educators and students to ensure the design met the desired needs. In particular, middle-school educators provided input regarding how the web-based experience could best be mapped to educational standards in math and science.

The web-based experience begins with Elena, an animated African-American, female character who is an engineering director faced with a new design challenge. Elena gives a brief background on the diversity of engineered products, and then addresses the user with regard to the design challenge. The problem statement at this point is ill-defined: "Senior citizens typically don't like the phones that high school and college students like. There are a number of issues with these phones when it comes to this population. So we're here to design a phone to help them feel more comfortable using them and meet their specific needs." Elena then tells the user that there are a number of ways to design, but typically design should begin with research to better understand the problem, then design, then testing the design, and finally presenting the final design to the client. Though Elena suggests these steps, the user is free to start at whatever point he or she desires. This ability to skip steps was purposefully added to the activity design, such that users who did not fully understand the problem by conducting research would build a design that likely did not meet the needs of the users. This helped demonstrate the importance of following the engineering process and designing with the user in mind, instead of one's self (a reason why the senior citizen market was chosen as the user population).

For those students who begin at research, they are presented a file folder of reports that they can look through. The topics are: Usage, Dimensions, Research Results, and Client Needs. The Usage and Dimensions topics feature various charts and graphs showing users' preferences. The graphs, ranging from pie charts to bar charts have to be carefully interpreted to determine what combination of preferences users expressed, such that this could then be accounted for in design. Research Results presents short summaries of interviews with potential users to better understand their needs. Each interview is presented separately, with the user able to determine how much information they wanted to consider. This was also purposeful, to reveal to students that one user is not typical of all. The Client Needs was simply a statement from the client who would be selling the phone. This helped students recognize what is termed the Designer-Client-User triangle.[11]

For those students who then move on to design, they are first presented a short informational discussion with Elena and the client. This is an opportunity to teach the student engineering-related content knowledge. The student is then presented with a number of options for designing the cell phone. These options include size, screen size, phone color, button size, screen brightness, button color, software, phone shape, recycled case, keyboard option, and rubber grip. With each decision made, the phone cost and remaining budget are updated. Battery life and phone weight are also displayed based on current decisions.

After completion of the design, students can choose to participate in testing. In Testing, the student is able to participate in a focus group with a number of users. Five users are shown on the screen, each clickable to see their feedback upon using the phone. The feedback these users provide is programmed to change based on how closely the student's design meets the desired design objectives. Regardless, not all subjects provide the same information, and in fact one of the individuals provides feedback untypical of the older adult population. This helps to again demonstrate to the student the challenge of meeting the needs of a diverse group.

Students then have the ability to return to the design stage to address the focus group's concerns, or to move forward and conclude the design as final. Once the design moves forward, the client comes back to show the sales results for six months. This is shown as a bar chart, setting forth goals for 1 month, 3 months, and 6 months, as well as the number sold. The client then discusses the implication of exceeding/not exceeding these set goals.

Elena wraps the activity up with an encouraging discussion about engineering careers, as well as options to print results for documentation, design a new phone, or start over from the beginning.

Additional resources on the website include a teacher's guide and profiles of "interesting people" in related careers. The teacher's guide offers tips for using the site, discussion and assessment activities, activity extensions to be used in the classroom (design a phone for a business person/design a phone for middle school students), and the mapped Ohio and National Science & Technology Standards. This resource helps maximize the learning experience when accompanied by additional facilitation, through either formal or informal settings.

Methods of Assessment

To assess the impact of the web-based experience on Grades 6-8, pre- and post-activity summative measures were taken using a web-based survey. In collaboration with a local school district and during conduction of regular classes, 162 students participated in the survey to measure knowledge and perceptions about engineering and engineering-related careers prior to participation in the Design a Cell Phone web-based experience.

The survey presented prior to the experience included six questions meant to test students' knowledge of engineered design and the engineering process. All questions were multiple choice. The first five questions had only one right response. The sixth question, regarding the steps of the engineering process was scored on how many features were correctly included. The questions, as well as the correct multiple choice answers, are included in Table 1.

Table 1. Survey Questions asked to Assess Student Knowledge and Perceptions

Question	Correct Response
1. What makes something engineered design rather than art?	*It has purpose.*
2. Who is involved in the engineering process?	*Many different people.*
3. The primary key elements of engineering design success are?	*Meeting the needs of the client and users.*
4. Good engineering design is meant to do what?	*Solve a problem.*
5. Which of the following statements is best for engineering design?	*Potential users tell engineers what the design should do.*
6. If you were asked to design a new type of chair what steps would you follow?	*Research-Design-Test-Redesign-Present*

Students then completed the web-based experience. Upon completion, 141 of the 162 students took part in the post-program assessment measures. The post-questionnaire consisted of the same six questions that had been included in the pre-assessment, as well as scaled questions to measure the participant's perceptions of engineering as a career and perceptions of the features of the web-based experience. For these scaled questions, students were asked to rate each of five questions on a scale of 1 to 7 (with 1 being strongly disagree and 7 being strongly agree). These questions are shown in Table 2.

Table 2. Scaled Questions asked Post-Experience to Measure Participant Perceptions of Engineering

Statement	Possible Score
1. Engineering is important in my daily life	1 – 7
2. I use engineered products all of the time	1 – 7
3. I could become an engineer if I wanted to	1 – 7
4. I can see myself in an engineering related career	1 – 7
5. I can see myself as an engineer	1 – 7

Post-experience, students were also asked a series of scaled questions regarding elements specific to the design of the web-based experience. These nine questions were again scaled 1 to 7 (with 1 being strongly disagree and 7 being strongly agree). These scaled questions are shown in Table 3.

Table 3. Scaled Questions asked Post-Experience to Measure Participant Perceptions of the Design of the Web-based Experience

Statement	Possible Score
1. Overall, the website is attractive	1 – 7
2. The web site has nice colors	1 – 7
3. The web site has good graphics	1 – 7
4. The web site is easy to navigate	1 – 7
5. The web site is enjoyable	1 – 7
6. The web site makes sense	1 – 7
7. The web site appeals to me	1 – 7
8. I like the characters on the web site	1 – 7
9. I would play the game again	1 - 7

To assess gain in knowledge, differences in the percentage of correct responses between pre- and post-experience were calculated for each question listed in Table 1. An independent sample t-test was run to determine whether the difference in the mean pre-test score and mean post-test score correct on this survey was statistically significant. To analyze the knowledge gain of males compared to females, an independent samples t-test was run on the data comparing the total correct scores of males with females. Each gender was then analyzed separately to determine knowledge gain based on pre- and post-program mean score, also using independent samples t-test.

To assess gender-differences in perceptions and interest in engineering, independent samples t-tests were run on each question shown in Table 2, comparing male and female scores. To assess gender-differences in perceptions of the design of the web-based experience, independent samples t-tests were run on each question shown in Table 3 to determine significance.

Results of Assessment

The results showing the knowledge gained about engineering after participating in the web-based experience are given in Table 4.

Table 4. Results from Questions Assessing Knowledge Gained by Participation

Question	Correct Answer	Pre-Experience % Correct	Post-Experience % Correct	Difference (Post – Pre)
What makes something engineering design rather than art?	It has purpose.	37.9%	69.8%	+31.9%
Who is involved in the engineering process?	Many different people.	50.3%	44.6%	-5.7%
The primary key elements of engineering design success are?	Meeting the needs of the client and users.	57.8%	82%	+24.2%
Good engineering design is meant to do what?	Solve a problem.	50.6%	69.1%	+18.5%
Which of the following statements is best for engineering design?	Potential users tell engineers what the design should do.	29.8%	52.2%	+22.4%
If you were asked to design a new type of chair for middle-school students, what would you do? What steps would you follow?	Research-Design-Test-Redesign-Present	0.6%	8.6%	+8%

Collectively, students answered all engineer-based knowledge questions more correctly after completing the Design a Cell Phone web-based activity, except for the questions regarding who is involved in the engineering process. On this question, the percentage of students who responded correctly after participating in the web-based experience decreased by approximately five percent.

Prior to participating in the Design a Cell Phone activity, students, on average, correctly answered 5.12 questions out of the possible 10 (Question 6 was a multiple part question that students got one point for each correct component selected). After completing the activity, the students, on average, scored 7.10 out of 10, an increase of 1.98. This difference was statistically significant at $p = 0.000$, suggesting that the activity increased the student's knowledge of what engineering is.

The results to determine whether gender differences in knowledge about engineering existed prior to participation in the web-based experience are shown in Table 5. For the pre-test, 76 males participated in the survey and 85 females.

Table 5. Gender Comparisons of Engineering-Based Knowledge Prior to Participation

Question	Correct Answer	Males % Correct	Female % Correct	Difference (Males – Females)
What makes something engineering design rather than art?	It has purpose.	31.6%	43.5%	-11.9%
Who is involved in the engineering process?	Many different people.	51.1%	49.4%	+1.7%
The primary key elements of engineering design success are?	Meeting the needs of the client and users.	55%	60%	-5%
Good engineering design is meant to do what?	Solve a problem.	52.6%	48%	+4.6%
Which of the following statements is best for engineering design?	Potential users tell engineers what the design should do.	27.6%	31.7%	-4.1%
If you were asked to design a new type of chair for middle-school students, what would you do? What steps would you follow?	Research-Design-Test-Redesign-Present	0%	1.2%	-1.2%

Overall, females answered more of the questions correctly than males. Individually, males on average correctly answered 4.63 of the 10 questions. Females, on average, correctly answered 5.55 of 10 questions correctly. This difference was statistically significant with $p = 0.026$. This suggested that females had a better understanding of what engineering was than male students prior to participation in the web-based activity.

The results to determine whether gender differences in knowledge about engineering existed after participation in the web-based experience are shown in Table 6. For the post-test, 76 males participated in the survey and 85 females.

Table 6. Gender Comparisons of Engineering-Based Knowledge After Participation

Question	Correct Answer	Males % Correct	Female % Correct	Difference (Males – Females)
What makes something engineering design rather than art?	It has purpose.	63%	75%	-12%
Who is involved in the engineering process?	Many different people.	42%	46.9%	-4.9%
The primary key elements of engineering design success are?	Meeting the needs of the client and users.	80.7%	82.7%	-2%
Good engineering design is meant to do what?	Solve a problem.	70.2%	69.1%	+1.1%
Which of the following statements is best for engineering design?	Potential users tell engineers what the design should do.	43.9%	58%	-14.1%
If you were asked to design a new type of chair for middle-school students, what would you do? What steps would you follow?	Research-Design-Test-Redesign-Present	5.3%	11.2%	-5.9%

Overall, females answered more correctly than males on all but one question. On average, male students correctly answered 7.0 of 10 questions after participating in the web-based activity. Females, on average, answered 7.2 of 10 questions correctly. This difference was not statistically significant. This suggests that females started with a slightly higher knowledge prior to the activity, but males gained more knowledge through the activity, resulting in almost equal scores.

The overall knowledge gain of males from a pre-experience score of 4.63 to a post-experience score of 7.0 was statistically significant at $p = 0.000$. Similarly females demonstrated a statistically significant knowledge gain after the activity, increasing their score from 5.55 to 7.2 ($p = 0.002$). This suggests the activity was helpful in increasing knowledge for both genders.

The results to determine attitudes and perceptions of engineering as a career are shown in Table 7.

Table 7. Comparison of Perception and Attitude Scores by Gender

Statement	Overall Mean Score	Male Mean Score	Female Mean Score	Statistically Significant p-value
Engineering is important in my daily life	5.27	5.75	4.93	$p=0.004$
I use engineered products all of the time	5.87	5.77	5.93	Not stat. sig.
I could become an engineer if I wanted to	4.61	5.19	4.22	$p = 0.005$
I can see myself in an engineering related career	4.07	4.86	3.51	$p < 0.000$
I can see myself as an engineer	3.49	4.40	2.85	$p < 0.000$

These results show that females agreed less strongly than males to all questions, with the exception of the statement "I use engineered products all of the time." Particularly notable was that females were less likely to agree that they could see themselves as an engineer or in an engineering-related career. For both genders, there was less agreement to the statements as the commitment toward engineering as a career increased – i.e. students were more likely to think they could become an engineer if they wanted to, less likely to see themselves in an engineering-related career, and even less likely to see themselves as an engineer.

With respect to perceptions of elements of the web-based activities, both males and females rated the elements of Table 3 positively. On average, all scores were 4.5 or higher, with many 5.5 or 6 out of 7. On average, females exhibited a slightly more favorable perception of the website, though this did not tend to be statistically significant.

Discussion

The results of this project provided important data to help guide future educational outreach endeavors, while providing further support about gender-differences in knowledge and perceptions of engineering.

The web-based activity, Design a Cell Phone, was received very favorably, as indicated by the results to the questions shown in Table 3. Particularly important was the way in which females perceived the web-based activity, as it was thought that video games might be a more male-dominated mode of delivery. The Design a Cell Phone activity was designed with this in mind such that the design presented a real-world, open-ended societal problem. The results of the activity's assessment demonstrate that females not only perceived the website positively, but even slightly more favorably than males. The lack of a statistically significant difference between genders indicated that the web activity met the needs of both groups, which is advantageous from a web-design perspective. This web-based activity also proved as an excellent way to maximize outreach efforts, with 1,131,299 unique users between its internet release in mid-June 2009 and November 1 2009. This demonstrates the power of dissemination that such an internet-based activity allows.

The results of this work's assessment also demonstrated that the Design a Cell Phone activity increased student knowledge about what engineering is. This suggests that similar web-based activities could be a potentially powerful means of furthering student knowledge about engineering and engineering design. The results of this study indicated that students increased their knowledge in certain areas more than others, as shown by the difference in the magnitude of knowledge gain between the pre- and post-test for the various questions. The difference in this gain is thought to be related to how the content information was presented in the web-based activity. For example, the largest overall gain was observed on the question "What makes something engineering design rather than art?" During the web-based experience, Elena, the animated character guiding the students, explicitly answered this question and talked about the difference. Some of the other questions were less explicitly stated and had to be inferred by the user based on their observations during the activity. Interestingly, for one question: "Who is involved in the engineering process?", the percentage of correct responses declined after participation in the activity. It is thought that this may have had something to do with the wording of the possible multiple choice answers. Throughout the activity, students saw many different people participating in the design process – but all had specific titles and roles (i.e. the client, the users, etc.) This may have led students to compartmentalize how they viewed the engineering design process and those involved in it.

With regard to gender, this study demonstrated that females had a greater knowledge about engineering prior to participating in the activity than males. This was somewhat of a surprise; however, further investigation was not conducted to determine where this knowledge came from. With the push to encourage females to increase knowledge of and participation in STEM careers, many middle-school-aged girls have had opportunities to participate in activities and experiences meant to expose them to engineering as a career. These more formal educational experiences, such as Girls Discover Engineering at the Center of Science and Industry in Columbus, Ohio, Introduce a Girl to Engineering Day at Ohio State University, and the Women in Engineering Summer Camp at the University of Dayton, may teach female students engineering knowledge content that male students do not get, as these same opportunities are not often catered to them. A positive aspect of the web-based experience was that participants, on average, ended at a similar knowledge level, regardless of the fact that male students started with a lower baseline content knowledge.

Despite having a fairly strong engineering-related content knowledge, after the activity females still did not express strong perceptions of seeing themselves in engineering-related fields. On a scale of 1 (strongly disagree) to 7(strongly agree), the mean response for females was only 2.85, largely on the "disagree" spectrum. This indicates that knowledge and perceptions do not go hand-in-hand, and that future work may make the most impact by focusing on these two pieces separately. The current work is limited, however, by the fact that students did not take the same perception survey prior to participation in the web-based activity. As such, it is unknown how perceptions changed due to the Design a Cell Phone activity. The hope was that because of the activity, attitudes and perceptions of engineering as a career would have not only improved but would also have been highly favorable by the completion of the activity. It is clear that the latter goal was not met, but it is possible that the former was.

To overcome this limitation, future work is needed to determine how perceptions about engineering change by participation in web-based activities. Future work is also needed to determine how to adapt the web-based engineering experience so that females are more likely to think favorably about seeing themselves in engineering-related careers. One of the benefits of web-based activities is that they can easily be designed to meet the preferences of the population they are intended for. For example, it was thought that using the animated character Elena, a "cool" African-American female engineering director, might make connections with the female students participating in the activity and help break down stereotypes of who engineers are. Though this study did not allow us to conclude how large of an impact this character had, it appears that it did not have enough. Future work thus aimed at determining how perception changes based on the characteristics of the lead animated character and also the nature of the problem to be solved would be beneficial. An additional avenue of importance for future work is to determine whether and to what degree changes in career-related perceptions based on use of a web-based activity are specific to the career field. For example, in the web-based Virtual Knee Surgery participants take on the persona of a surgeon. It would be important to determine whether, based on this experience, students were more likely to see themselves in healthcare-related careers, and particularly as a surgeon. The responses could then be mirrored to what was observed based on Design a Cell Phone and the responses regarding careers in engineering. This would ultimately reveal whether the effectiveness of the web-based activity at changing perceptions was specific to the career being explored, or whether the web-based activity was overall a better tool to convey knowledge and content but did not leave a lasting impression on the career perceptions of participants.

The findings of this work, and related-future work, are important to help assess whether web-based activities might be a solution to increasing the number of females interested in STEM-related careers. The assessment of the Design a Cell Phone activity demonstrates that such an activity can be widely disseminated, increased knowledge about engineering, and is well-liked by both genders. A challenge is determining whether this same medium can be altered to also maximize its impact on changing perceptions of engineering as a career, the ultimate goal of this and related projects.

Conclusion

This work presented a creative web-based activity where users took on the persona of an engineer to "do design". The design problem was purposefully chosen to focus on meeting a societal need: the difficulty older adults have with using cell phones. The results of the assessment of the web-based activity demonstrate that the target audience of middle-school students gained significant knowledge about engineering content by participation in the activity. With over one million unique users since the website launch, it was also observed to be a mode of delivery that maximizes dissemination. Users, both female and male, rated the web-based experience elements favorably, suggesting enjoyment at participating. These findings frame the web-based activity as a potential powerful tool. However, despite participating in the web-based activity, students, particularly females, expressed low perceptions of having an engineering-related career themselves. Future work is now needed to determine how to best build in this element to the web-based activity.

Acknowledgements

This work was funded by a 2008 Motorola Inc. Innovation Generation Grant. The authors would also like to recognize ILI Evaluation and Research Institute, who served as the external evaluator for this work.

Bibliography

1. National Academy of Engineering. 2008. Changing the Conversation. Washington D.C.: The National Academies Press.
2. National Academy of Engineering. 2002. Raising Public Awareness of Engineering. L. Davis and R. Gibbin, eds. Washington, D.C.: The National Academy Press
3. Cunningham, C., C. Lachapelle, and A. Lindgren-Streicher. 2005. Assessing Elementary School Students Conceptions of Engineering and Technology. Proceedings of the 2005 American Society for Engineering Education Annual Conference and Exposition. Portland, Ore., June 12-15. Washington, D.C.: ASEE.
4. Cunningham, C., and M. Knight. 2004. Draw an Engineer Test: Development of a Tool to Investigate Students' Ideas about Engineers and Engineering. Proccedings of the 2004 American Society for Engineering Education Annual Conference and Exposition. Salt Lake City, Utah, June 20-23. Washington, D.C.: ASEE.
5. Harris Interactive. 2004. American Perspectives on Engineers and Engineering. Poll conducted for the American Association of Engineering Societies. Final report, February 13, 2004. Available online at *http://www.aaes.org/harris_2004_files/frame.htm*. (December 31, 2009)
6. National Science Foundation. 2009. Program Solicitation 09-553: Informal Science Education. Available online at *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5361*.(January 7, 2010)
7. Girl Scouts of the United States of America. 2004. Girls Go Tech website. Available online at *http://www.girlsgotech.org*. (January 5, 2010)
8. National Academy of Engineers. 2003-2009. Engineer Girl website. Available online at *http://www.engineergirl.org*. (January 6, 2010)
9. Bloom, B., ed. 1956. Taxonomy of Educational Objectives: The Classification of Educational Goals; Handbook I, Cognitive Domain. New York: David McKay
10. IBM, Institute of Electrical and Electronics Engineers, TryScience. Try Engineering website. Available online at *http://www.tryengineering.org/play.php*. (January 6, 2010)
11. Dym, C. and P. Little. 2008. Engineering Design: A Project-Based Introduction. John Wiley and Sons Inc.
12. Agosto, D. 2004. Design vs. Content: A Study of Adolescent Girls' Website Design Preferences. International Journal of Technology and Design Education. 14: 245-260.
13. Gibbons, M. 2007. Engineering by the Numbers. American Society of Engineering Education 2007 Engineering Profile. Available online at *http://www.asee.org/publications/profiles/upload/2007ProfileEng.pdf*. (January 7, 2010)
14. Jacobs, J. and S. Simpkins. 2005. Mapping Leaks in the Math, Science, and Technology Pipeline. New Directions for Child and Adolescent Development.110: 3-6.
15. Steinke, J. 1997. A Portrait of a Women as a Scientist: Breaking Down Barriers Created by Gender-Role Stereotypes. Public Understanding of Science. 6: 409-428.
16. Tiedemann, J. 2002. Teachers' Gender Stereotypes as Determinants of Teacher Perceptions in Elementary School Mathematics. Educational Studies in Mathematics. 50: 49-62.
17. Valian, V. 1999. Why So Slow? The Advancement of Women. Cambridge: MIT Press.

18. Clewell, B. and K. Darke. 2000. Summary Report on the Impact Study of the National Science Foundation's Program for Women and Girls. The Urban Institute Education Policy Center: Washington D.C.
19. Campbell, P., E. Jolly, and L. Perlman. 2002. Upping the Numbers: Using Research-based Decision Making to Increase the Diversity in the Quantitative Disciplines. Newton, Massachusetts: Education Development Center, Inc.
20. Loftus, M. 2007. Why won't she listen? American Society of Engineering Education PRISM. 17. Available at *http://*www.prism-magazine.org/dec07/feature_generation-gap.cfm. (January 7 2010)
21. Edheads. 2000-2010. Design a Cell Phone website. Available on-line at *http://www.edheads.org/activities/eng_cell.* (January 7, 2010)