First-Year Students' Attitudes towards the Grand Challenges and Nanotechnology

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Abstract

The *Grand Challenges* for Engineering are an effort to portray engineering as a field that has profound impacts on society. This study explores the level of interest first-year engineering students had in various *Grand Challenges* and in nanotechnology topics. We administered a survey to a large sample of students enrolled in a pre-engineering course at a four-year, research- focused institution. The survey measured students' interest in nanotechnology and the *Challenges*, their perception of the relationship between nanotechnology and the *Challenges*, and their attitudes and self-reported knowledge about nanotechnology. The most interesting topics related to high-profile issues, such as reverse-engineering the brain, as well as topics that have a pro-social component, such as access to clean water. For female students, advancing health informatics and engineering better medicines were especially interesting, while URM students were more drawn to nanotechnology and virtual reality. These results will help educators developing engineering curricula emphasize engaging topics that better promote persistence and diversity in engineering.

Keywords: Grand Challenges, First-year engineering programs, Diversity, sex differences

First-Year Students' Attitudes towards the Grand Challenges and Nanotechnology

The field of engineering, led by the National Academy of Engineering, is making increasing efforts to portray engineering as an important and exciting field of study that has profound impacts on society (Vest, 2008).[1] This movement, exemplified by *Changing the Conversation* (National Academy of Engineering [NAE], 2008a) and *Messaging for Engineering* (National Academy of Engineering, 2013) campaigns, is intended to address various challenges to the field of engineering. Among those challenges are, first, a lack of interest in engineering among U.S. college students that limits the number of U.S.-citizen students entering undergraduate and graduate engineering programs (National Science Foundation [NSF], 2014). Second, a nationally perceived need to increase the diversity of students engaging in engineering majors, in terms of gender, race/ethnicity, and socioeconomic status (Augustine, et al., 2010; Olson & Riordan, 2012). To address both of these issues, *Changing the Conversation* and *Messaging* reflect an implicit theory that there is a perceived mismatch between some students' preference for careers that serve a communal or altruistic goal and the affordances of engineering, which may be perceived as a field that offers more opportunity to fulfill status and individualistic values. The NAE campaigns are therefore designed to challenge common perceptions of engineering and increase the number and diversity of students interested in engineering college majors and careers.

A growing body of literature indicates that women are more likely to prefer altruistic and communal career values, but perceive engineering as a field that is less supportive of these values and offers fewer affordances to engage these values (Diekman, Brown, Johnston, & Clark, 2010; Weisgram, & Bigler, 2006). These communal or altruistic goals may also be more common among some race/ethnicity groups that are underrepresented in engineering (Wade, 2012). Therefore, it is essential for initiatives that seek to increase the size and diversity of the engineering degree pool to address this perceived lack of altruistic and communal affordances in engineering.

The Grand Challenges

The NAE has been at the forefront of an effort to change common perceptions of engineering in order to increase student interest and diversity of engineering career fields. Many researchers and policy makers in engineering have argued that engineering curricula should capitalize on students' areas of interest to promote engineering persistence and student learning. A key example is the 2008 publication from the NAE called *Changing the Conversation*, which resulted from a collaboration with a marketing company to better communicate the importance and excitement of engineering work to students and the broader U.S. population (NAE, 2008a, 2013; Litzler & Lorah, 2013; Vest, 2008). As a further step in this area, the NAE introduced the Engineering *Grand Challenges*, which was developed as a framework of topics that are intended to be highly interesting and motivating to engineering students (NAE, 2008b). The fourteen *Challenges* highlight key issues and obstacles facing modern society that reinforce the engineering messages of how engineers and their creative problem solving skills are essential to improving our world and shaping the future. See Table 1 for a list of the *Grand Challenges*.

National Nanotechnology Initiative

In addition to broad marketing tactics to promote engineering as an exciting and rewarding career, there are further coordinated efforts to promote interest in engineering through nanotechnology concepts. Nanotechnology is becoming pervasive in our world. It is expected that by next year over 15% of total global manufactured goods are will be nanotechnology enabled (Project on Emerging Nanotechnologies, 2013). Therefore, engineers need to be prepared to enter nanotechnology related careers. The development of a skilled nanotechnology (or "nanoliterate") workforce is one of the goals of the National Nanotechnology Initiative (National Nanotechology Initiative, n.d.). To

[1] This paper was adapted from Davis, Lakin, Davis, & Raju (2016).

Challenge	How nanotechnology may help address challenge[a]
Make solar energy economical	Reduced manufacturing cost and flexible forms, improved efficiency through self-cleaning surfaces and more efficient light to energy conversion
Provide energy from fusion	Improved materials for reactor walls, smaller more durable robots for maintenance and repair.
Develop carbon sequestration methods	Nanostructured CO2 sorbants, analysis of geological structures, Ni catalyst for CO2 conversion to CaCO3
Challenge	How nanotechnology may help address challenge[a]
Manage the nitrogen cycle	Better methods for application of fertilizer, controlled release materials, sensors
Provide access to clean water	Nanostructured membranes for desalination and decontamination, nanoparticles for contaminant absorption, sensors)
Restore and improve urban infrastructure	New load bearing materials that are cheaper and easier to install, protective coatings to increase life span and improve aesthetics of structures, sensors
Advance health informatics	Nanoinformatics, modification of bioinformatics approaches to advance nanomedicine, advances in computer technology
Engineer better medicines	Faster systems to asses patient genetic profile, nanoparticles as a mode of drug delivery, nanostructured scaffolds for wound repair and artificial organ growth
Reverse-engineer the brain	Better medical imaging, neural implants
Prevent nuclear terror	Nanophotonic radiation detectors
Secure cyberspace	Better authentication methods, advances in computing capability
Enhance virtual reality	Better resolution displays, responsive materials to replicate the sensations of sound, touch, and motion.
Advance personalized learning	Nanoenabled advances in neural science aspects of learning
Engineer the tools of scientific discovery	Quantum computing, further advances in characterization instrumentation

[a] These alignments were developed by third author in collaboration with the grant PI.

Table 1. National Academy of Engineering "Engineering Grand Challenges"

address this need, over the last decade, there have been a range of initiatives focused on introducing students to nanotechnology concepts through formal and informal education (Dyehouse, Diefes-Dux, Bennett, & Imbrie, 2008). As a result, engineering schools anecdotally report seeing the impacts of these programs reflected in the interest of the entering freshman, who express interest in nanotechnology courses.

Although the *Grand Challenges* do not explicitly mention nanotechnology, nanotechnology's impact is expected to be on par with the development of the personal computer or automobile (Project on Emerging Nanotechnologies, 2013); therefore, nanotechnology can readily be connected to engineering *Grand Challenges*. In some cases, such as "Provide Access to Clean Water," nanotechnology is already making an impact through improved filtration and desalination membranes, and higher specific surface area filtration media. The potential connections between the *Grand Challenges* and the role of nanotechnology in the solutions are shown in Table 1 and can be presented in ways that are readily accessible to freshmen engineers and appeal to the range of backgrounds and learning styles.

As a result of this alignment between nanotechnology and the *Grand Challenges*, and the expected interest that both topics are believed to incite, the use of a combined nanotechnology- *Grand Challenges* curriculum could be especially interesting and engaging to modern engineering students. The synergy of these two areas and their potential impact on students is therefore important to explore.

The goal of this research study was to understand the level of interest first-year engineering students at a four-year institution had in various *Grand Challenges* and in nanotechnology topics. We were interested in whether nanotechnology was rated as being at least as interesting as the *Challenges* and whether students saw a clear link between nanotechnology and solutions to these *Challenges*. We were further interested in the attitudes these students had towards nanotechnology and the relationship between these interest measures and student background characteristics. This study is a first step in identifying a causal relationship between engineering curricula that emphasize *Grand Challenges* and nanotechnology and promoting persistence and diversity in engineering college majors. To address this purpose, the following research questions were addressed:

1. Which of the *Grand Challenges* are most interesting to students?
   a. Is nanotechnology an area of interest for most students? How does it rank relative to the *Grand Challenges*?
2. Do female, African American, or Latino students report more interest in some topics compared to male, white, or Asian students?
3. Do students see nanotechnology as critical to many *Grand Challenges*?
4. Do students generally hold positive or negative attitudes towards nanotechnology?

Methods

In this study, we administered a survey on engineering attitudes to a large sample of first- year students enrolled in a pre-engineering introductory course at a large four-year, research- focused institution. Data was collected in four semesters from 2014 to 2016. The survey included scales related to students' interest in nanotechnology and the *Grand Challenges,* their perception of the relationship between nanotechnology and the *Grand Challenges,* and their attitudes about nanotechnology. In addition, we collected their race/ethnicity and gender. We were interested in the descriptive statistics related to student interests as well as differences in interests between male and female students as well as underrepresented minority (URM) students compared to non-URM students. URM was defined as an African American or Latino students.

Participants

The university involved in this study offers a series of pre-engineering courses designed to offer students an opportunity to learn more about the key concepts in their intended major as well as help them develop or review the fundamental skills needed for advanced engineering coursework. To gather a representative sample of the pre-engineering majors at this university, we therefore approached the instructors of each section of the introductory courses (required for all pre-engineering majors) to allow their students to participate. Each semester, at least half of the faculty, representing a wide variety of engineering fields (chemical engineering, biosystems, etc.), agreed to distribute the survey. This survey usually occurred within the first two weeks of the semester and was conducted (within the exception of one instructor) online.

A total of 1,217 students completed the survey. According to institutional records, 1, 300 first-time freshmen enroll in Engineering each fall, so, excluding transfer students in our sample, this sample represents almost half of the eligible students. Most students from participating faculty volunteered to complete the survey, although they had to be present in class to be eligible or access the survey through their course website. Therefore, this sample likely excludes students who are not attending their pre-engineering classes regularly and those who do not moni-

Demographic variable	N	%
Total	1217	
Gender		
Male	702	72.1
Female	271	27.8
Missing[a]	244	
Race		
Non-Hispanic White	795	83.3
Non-Hispanic African American	61	6.4
Non-Hispanic Asian	45	4.7
Hispanic	32	3.4
Other	21	2.2
Missing[a]	263	

Note. [a] Missing data includes students who declined to answer the question as well as 87 of the fall 2014 paper surveys that accidentally omitted the demographics page.

Table 2. Descriptive statistics of sample

tor their course site, which could include less motivated or committed engineering students.

Along with the attitude scales, students were asked to report their gender, race, and ethnicity. Table 2 shows the percent of students in each category. A photocopying error in fall 2014 meant that roughly 20% of surveys that semester (87) did not include the demographic questions. For these students, all other scales were included in the general analyses, but they are excluded from group comparisons based on background characteristics in the results section.

Typical of most engineering programs, the student makeup was predominantly white and Asian (88%), while just 12% came from underrepresented minority groups. Just 28% of the students were female, which is also typical of engineering fields. This percent is actually somewhat high because the freshman engineering class at this university was 18% female according to institutional reports.

Instruments

A battery of attitude scales was assembled for the purposes of this study from the related literature. The scales and their related research are described below. See the Appendix for the complete scales.

Interest in Grand Challenges and Relevance of Nano

Part of the motivation for this study was to develop measures that could be used for a curriculum development project that involved connecting nanotechnology to the *Grand Challenges* in order to enhance student interest and teach nanotechnology literacy. It was hypothesized that nanotechnology would be interesting to many students and the link between nanotechnology and Grand Challenges would heighten interest in course content.

To accomplish these goals, students were first asked to rate the 14 *Challenges* and nanotechnology in terms of how interesting they find the issue to be. We used a four point scale—not interesting, somewhat interesting, interesting, and extremely interesting—with an option to indicate that the respondent did not know about this topic, which was treated as a separate category. Survey scales are presented in an appendix.

Ratings of interest do not necessarily need to form a unidimensional scale, but in this case we found that ratings did form a strong unidimensional scale with a Cronbach's α of 0.87. Exploratory factor analysis (Costello & Osborne, 2005) confirmed a strong first factor underlying the ratings, indicating that students had a tendency to be somewhat uniformly interested or disinterested in the *Grand Challenges* topics.

Relevance of Nano to Grand Challenges

After rating the topics in terms of interest, students were asked to rate the same topic areas in terms of how critical the respondent thought nanotechnology was to solving that challenge. The prompt stated:

> Nanotechnology, including nanomaterials, is a key area of engineering development. How critical do you think nanotechnology is to solving the following engineering challenges?

Again, we used a four point scale (unrelated to issue, somewhat important, important, and critically important) plus an option to indicate that the respondent did not know. In this case, 14 prompts, excluding the nanotechnology topic, were presented.

Attitudes towards Nano

Finally, students' attitude towards nanotechnology and its role in society was assessed using a seven-point bipolar scale (ranging -3 to 3) with antonym pairs at the two extremes of the rating scale. This measure was adapted with a slightly different scale from Castellini et al. (2007; their scale was 1-4 with no midpoint). The antonym pairs were harmful-beneficial, dangerous- safe, unimportant-important, uncomfortable-comfortable, and boring-exciting. In a sample of 135 people who ranged from middle-school children to adults, Castellini et al. found that public opinion tended towards the positive attributes, with beneficial vs. harmful showing a strong preference for beneficial over harmful as an descriptor of nanotechnology as well as a preference for important over unimportant. This scale also showed strong internal consistency in this study sample (Cronbach's α = 0.83).

Analysis

Analysis began with descriptive statistics. We then compared the attitude scales across demographic groups—male vs. female students and students who are URM vs. non-URM (Asian and white students)—using t-tests.

Results

The first research question was primarily descriptive—Which *Grand Challenges* are most interesting to students? Figure 1 shows the average interest ratings of various engineering topics, including the 14 *Grand Challenges* as well as nanotechnology and nanomaterials. Note that these averages exclude students who indicate they did not know what the topic meant, so these interest ratings only include students who had some idea of the meaning of each topic.

Five topics stood out as broadly interesting to students: "Creating tools…", "Solar energy", "Access to clean water", "Energy from fusion", and "Reverse-engineer the brain". Nanotechnology, a particular focus of this project, ranked in the middle of the *Grand Challenges* with respect to average interest. It had a mode response of "interesting" (2 on a scale of 0-3) and an average rating of 1.65. Advance health informatics (236) Advance personalized

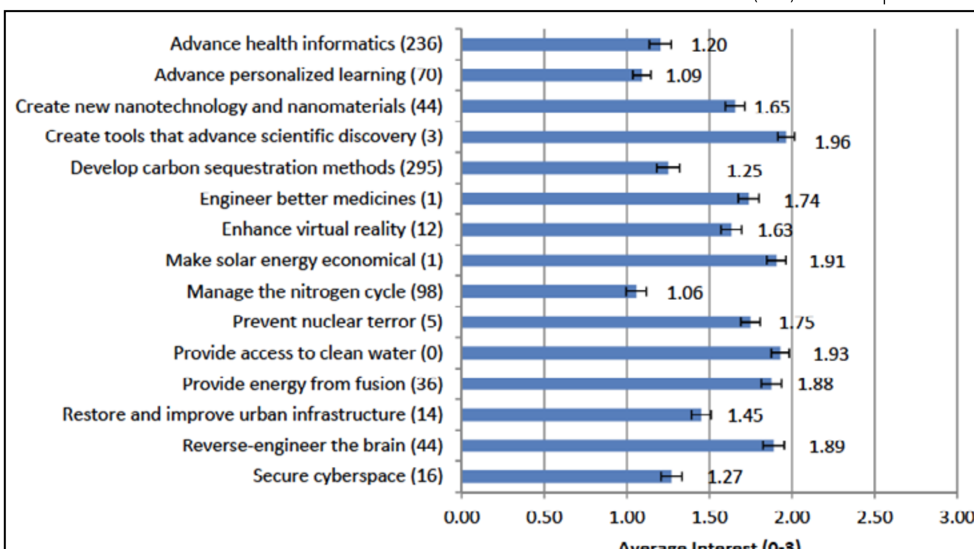

Figure 1. Average interest (scale of 0-3) in each of the engineering topics. The average and median of SDs = 0.97. In parentheses are the number of students who did not answer that question or indicated they "don't know what this is" for that topic.

	Female		Male		t *	Sig.	Cohen's d
	M	SD	M	SD			
Advance health informatics	1.61	1.00	0.99	0.89	8.02	<.001	0.65
Advance personalized learning	1.42	0.90	0.98	0.87	6.81	<.001	0.51
Create new nanotechnology and nanomaterials	1.55	1.00	1.69	0.93	-1.94	.053	-0.15
Create tools that advance scientific discovery	1.87	0.94	2.02	0.79	-2.40	.017	-0.18
Develop carbon sequestration methods	1.22	1.00	1.29	0.97	-0.77	.440	-0.07
Engineer better medicines	2.05	0.99	1.59	1.03	6.43	<.001	0.46
Enhance virtual reality	1.45	0.99	1.70	1.04	-3.39	.001	-0.25
Make solar energy economical	1.84	1.04	1.94	0.93	-1.48	.141	-0.11
Manage the nitrogen cycle	1.16	1.01	1.03	0.95	1.77	.077	0.13
Prevent nuclear terror	1.64	1.04	1.81	0.93	-2.42	.016	-0.18
Provide access to clean water	2.10	0.91	1.86	0.90	3.63	<.001	0.26
Provide energy from fusion	1.59	1.04	1.99	0.94	-5.47	<.001	-0.41
Restore and improve urban infrastructure	1.38	0.98	1.49	0.99	-1.51	.131	-0.11
Reverse-engineer the brain	2.02	1.04	1.83	1.05	2.50	.013	0.19
Secure cyberspace	1.07	0.99	1.35	1.05	-3.84	<.001	-0.27

Note. Positive Cohen's *d* effect size indicated stronger interest for female students. Negative effect sizes indicate stronger interest for male students. * t-test degrees of freedom ranged from 747 to 964 depending on the number of missing data (including "don't know" answers).

Table 3. Differences in interest across genders

	Non-URM		URM				Cohen's d
	M	SD	M	SD	t *	Sign.	
Advance health informatics	1.16	.959	1.28	1.027	-1.01	.31	-0.12
Advance personalized learning	1.08	.898	1.32	.866	-2.43	.02	-0.27
Create new nanotechnology and nanomaterials	1.61	.946	2.00	.922	-3.66	<.001	-0.42
Create tools that advance scientific discovery	1.98	.832	1.97	.867	.09	.92	0.01
Develop carbon sequestration methods	1.25	.952	1.44	1.125	-1.30	.20	-0.18
Engineer better medicines	1.71	1.035	1.80	1.065	-.78	.43	-0.08
Enhance virtual reality	1.61	1.034	1.85	.950	-2.29	.02	-0.24
Make solar energy economical	1.89	.962	2.07	.909	-1.73	.08	-0.19
Manage the nitrogen cycle	1.07	.961	1.02	1.029	.39	.70	0.04
Prevent nuclear terror	1.77	.962	1.66	.993	1.08	.28	0.11
Provide access to clean water	1.92	.912	1.97	.897	-.54	.59	-0.06
Provide energy from fusion	1.88	.983	1.79	1.054	.83	.41	0.09
Restore and improve urban infrastructure	1.45	.986	1.57	.976	-1.09	.28	-0.12
Reverse-engineer the brain	1.87	1.046	1.91	1.084	-.37	.71	-0.04
Secure cyberspace	1.25	1.041	1.45	1.033	-1.88	.06	-0.20

Note. Negative Cohen's *d* effect size indicated stronger interest for URM students. * t-test degrees of freedom ranged from 740 to 954.

Table 4. Differences in interest across race/ethnicity groups

learning (70)

Three topics garnered a larger number of "don't know" responses from students: Carbon sequestration (n=295), health informatics (n=236), and managing the nitrogen cycle (n=98). These topics may become familiar and interesting to more advanced students, but they are unlikely to be topics that draw students to engineering in the same way other, more widely known, issues may. It is also possible that the framing of these topics in formal language makes these topics seem unfamiliar and different wording would be more effective.

Group Differences in Interest

In addition to the overall interest of the topics, in our second research question, we were also interested in whether traditionally underrepresented groups of students, including female, African American, and Latino students in engineering, showed differences in interests compared to more strongly represented groups of students (male, white, and Asian students).

For male and female students, several significant differences in interest appeared. See Table 3. Topics that were significantly more interesting for female students and that had the largest effect sizes were advancing health informatics, engineering better medicines, and advancing personalized learning. Topics that appealed more to male students included providing energy from fusion, securing cyberspace, and enhancing virtual reality.

Comparing URM racial/ethnic groups to non-URM students (see Table 4), we found that URM students had significantly stronger interest in personalized learning, nanotechnology, and enhancing virtual reality.

Relationship of Nanotechnology to Grand Challenges

Because of our particular interest in students' perceptions of nanotechnology, to address our third research question, we asked them to rate how relevant they felt nanotechnology was to solving the *Grand Challenges*. This allowed us to assess whether freshman students see nanotechnology and nanomaterials as central to engineering solutions and whether *Grand Challenges* are an avenue for promoting nanoliteracy.

Figure 2 shows the average rating of how relevant students felt nanotechnology was to each of the other engineering challenges. The topics that seemed most related to nanotechnology were tools to advance scientific discovery, engineering better medicines, and reverse-engineering the brain. Personalized learning, nuclear terror, and urban infrastructure were not perceived by these students to have strong links to nanotechnology solutions.

Attitudes towards Nanotechnology

Our final research question asked whether students held generally positive or negative attitudes about nanotechnology. When students were surveyed on their attitudes towards nanotechnology, their feelings were mostly positive, with average ratings of .9 to 1.9 on a scale of -3 to 3, which indicated moderate to strong positive ratings on nanotechnology's benefits, safety, importance, comfort, and excitement. See Table 5. There were no significant differences between race groups[2], but it did seem that women had slightly less positive views of nanotechnology than men in this sample (Table 6).

Discussion

Although student interest will vary by campus, and should be explored in future research, the results of this study provide a baseline estimate that may be compared to results at other institutions. Comparisons to more liberal arts and undergraduate-focused institutions would be of interest. Several topics were found to be especially interesting to students: creating tools to advance scientific discover, solar energy, access to clean water, energy from fusion, and reverse-engineer the brain, with fusion and

[2] These analyses were conducted, but are not included in this paper, because no significant differences were found.

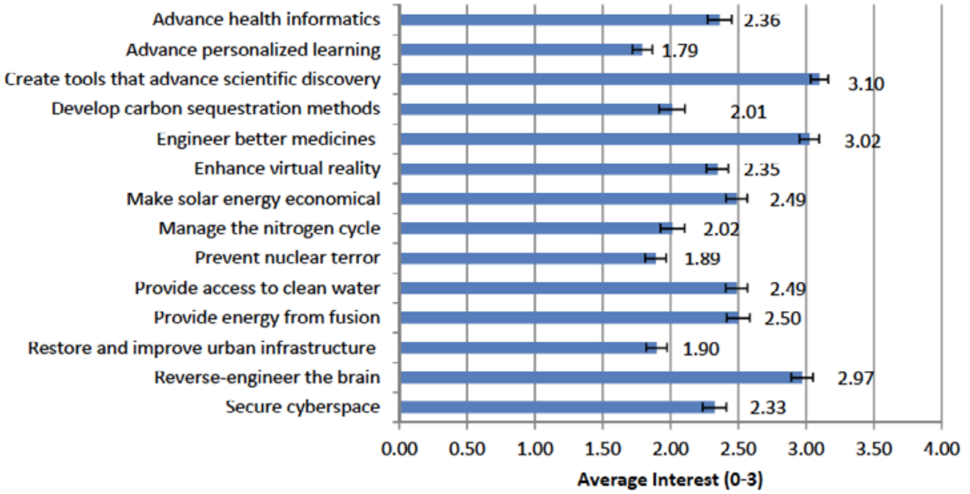

Figure 2. Average ratings (scale of 0-4) of how important nanotechnology is to addressing the 14 Grand Challenges. The average and median of SDs = 1.33.

brain topics garnering the most "extremely interesting" ratings. These topics could be a particular focus of engineering curricula because, not only are they highly interesting to students, but they also have clear links to helping society and promoting the well-being of others (Vest, 2008). Therefore, classes or projects organized around these topics would appeal to students with communal and individualistic career goals (Diekman, et al., 2010; Krapp, 1999; Weisgram, & Bigler, 2006). Further, we believe these topics lend themselves readily to authentic and complex class projects that promote engineering skills.

It should be noted that we did not assess students' comprehension of the topics; therefore, these ratings may not be based on accurate conceptions. However, if course and program topics are focused on *Grand Challenges*, as they are defined by their titles, then the results still give us an indication of how appealing these topics are—and how likely to spark excitement for a course or program—for freshman engineering students. Topics with lower average interest scores and large numbers of "don't know" ratings might benefit from changes in terminology or greater coverage in early engineering courses to highlight their importance and potential interest for students.

When selecting course topics to appeal to a broad range of students, this study confirmed previous findings that female students are more likely to be interested in biomedical topics and topics that promote human health and well-being (Capobianco & Yu, 2014). For female engineering majors, advancing health informatics, engineering better medicines, and advancing personalized learning were more interesting relative than they were for male engineering majors. Therefore, choosing class topics and projects related to these fields may have a particular effect on enhancing the interest of female students.

Topics that appealed more to male students included providing energy from fusion, securing cyberspace, and virtual reality. URM race/ethnicity groups were especially interested in personalized learning, nanotechnology, and enhancing virtual reality. This evidence of differences in interests supports instructional practices that sample broadly from the *Grand Challenges*. In other words, instructors who incorporate examples or projects from several *Grand Challenges* will best serve students and could promote interest among traditionally underrepresented groups. Future research is needed to directly evaluate the impact that interest alignment in engineering courses has on class interest and major persistence.

Nanotechnology, a particular focus of this project, ranked in the middle of the *Grand Challenges* with respect to average interest. It was most often rated "interesting" by students (2 on a scale of 0-3). We might conclude on this evidence that nanotechnology is not, in itself, bringing more students to engineering compared to other topics. However, there is evidence that nanotechnology can be paired with other *Grand Challenges* to promote engineering interest and nanoliteracy. The topics that seemed most related to nanotechnology included two that were among the most interesting to all students— reverse-engineering the brain and tools to advance scientific discovery—and a topic that was highly interesting for female students--engineering better medicines. These topics are, therefore, especially promising as topics that promote interest in engineering as well as promoting nanoliteracy.

The generally positive attitude of students toward nanotechnology further lends support to interventions that use *Grand Challenges* and nanotechnology combined to promote interest and persistence in engineering programs. When compared to the Castellini et al. (2007) study (adjusting our scale to fit their 1-4 scale), we found that our sample had generally more positive attitudes towards nanotechnology with a higher preference for "beneficial", "safe", "important", "comfortable", and "exciting" over their antonyms. This may reflect changes in attitudes over the last eight years, more positive attitudes towards nanotechology among younger samples, or changes in the rating scale.

Summary

As the *Grand Challenges* are increasingly incorporated into engineering curricula (Litzler & Lorah, 2013; Vest, 2008), more research is needed on the degree to which *Grand Challenges* appeal to students, enhance interest, promote diversity, and promote persistence in engineering. We also need to consciously evaluate efforts to incorporate *Grand Challenges* into curricula in order to understand which strategies work best for prompting interest and persistence among diverse student populations.

Given the interdisciplinary nature of nanotechnology, and the increasing presence of nanotechnology in everyday life, all engineers, not just a few specialists, will need to be nanoliterate to perform their jobs in the future (National Nanotechnology Initiative, n.d.). Therefore, an important goal of future research and curriculum development is to incorporate nanotechnology throughout in the standard engineering curriculum in a way that promotes student interest and persistence. Our findings in this study indicate that nanotechnology in itself may appeal to a limited range of students, but that students recognize the critical role that nanotechnology plays in solving many of the *Grand Challenges*. We also confirmed that students, at least at this institution, have generally positive and

	M	SD
Harmful vs. Beneficial	1.86	1.149
Dangerous vs. Safe	0.94	1.308
Unimportant vs. Important	1.83	1.333
Uncomfortable vs. Comfortable	0.97	1.319
Boring vs. Exciting	1.50	1.482

Table 5. Average attitudes towards nanotechnology (scale -3 to 3)

	Female		Male		t *	Sig.	Cohen's *d*
	M	SD	M	SD			
Harmful:Beneficial	1.67	1.182	1.93	1.126	-3.128	**.002**	**-0.23**
Dangerous:Safe	0.84	1.204	0.98	1.345	-1.427	.154	-0.11
Unimportant:Important	1.69	1.434	1.87	1.294	-1.789	.074	-0.13
Uncomfortable:Comfortable	0.82	1.259	1.03	1.338	-2.166	**.031**	**-0.16**
Boring:Exciting	1.30	1.522	1.59	1.456	-2.713	**.007**	**-0.19**

Table 6. Sex differences in attitudes towards nanotechnology (scale -3 to 3)

inquisitive attitudes towards nanotechnology. Engineering curricula could capitalize on this positive attitude and synergy of topics to promote engineering and nanotechnology knowledge.

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Appendix

Survey Scales

Which of the following trends or challenges in engineering do you find interesting?

	Don't know what this is	Not interesting	Somewhat interesting	Interesting	Extremely interesting
1. Advance health informatics	○	○	○	○	○
2. Advance personalized learning	○	○	○	○	○
3. Create new nanotechnology and nanomaterials	○	○	○	○	○
4. Create tools that advance scientific discovery	○	○	○	○	○
5. Develop carbon sequestration methods	○	○	○	○	○
6. Engineer better medicines	○	○	○	○	○
7. Enhance virtual reality	○	○	○	○	○
8. Make solar energy economical	○	○	○	○	○
9. Manage the nitrogen cycle	○	○	○	○	○
10. Prevent nuclear terror	○	○	○	○	○
11. Provide access to clean water	○	○	○	○	○
12. Provide energy from fusion	○	○	○	○	○
13. Restore and improve urban infrastructure	○	○	○	○	○
14. Reverse-engineer the brain	○	○	○	○	○
15. Secure cyberspace	○	○	○	○	○

Nanotechnology, including nanomaterials, is a key area of engineering development. How critical do you think <u>nanotechnology</u> is to solving the following engineering challenges?

	Unsure	Unrelated to issue	Somewhat important	Important	Critically important
1. Advance health informatics	○	○	○	○	○
2. Advance personalized learning	○	○	○	○	○
3. Create tools that advance scientific discovery	○	○	○	○	○
4. Develop carbon sequestration methods	○	○	○	○	○
5. Engineer better medicines	○	○	○	○	○
6. Enhance virtual reality	○	○	○	○	○
7. Make solar energy economical	○	○	○	○	○
8. Manage the nitrogen cycle	○	○	○	○	○
9. Prevent nuclear terror	○	○	○	○	○
10. Provide access to clean water	○	○	○	○	○
11. Provide energy from fusion	○	○	○	○	○
12. Restore and improve urban infrastructure	○	○	○	○	○
13. Reverse-engineer the brain	○	○	○	○	○
14. Secure cyberspace	○	○	○	○	○

Considering each pair of descriptors below, which one better describes your attitude towards nanotechnology in society?

Harmful						**Beneficial**
○	○	○	○	○	○	○
-3	-2	-1	0	1	2	3
Dangerous						**Safe**
○	○	○	○	○	○	○
-3	-2	-1	0	1	2	3
Unimportant						**Important**
○	○	○	○	○	○	○
-3	-2	-1	0	1	2	3
Uncomfortable						**Comfortable**
○	○	○	○	○	○	○
-3	-2	-1	0	1	2	3
Boring						**Exciting**
○	○	○	○	○	○	○
-3	-2	-1	0	1	2	3