2006-1470: USING RESEARCH TO EDUCATE FRESHMAN ENGINEERS AND HIGH SCHOOL STUDENTS ABOUT THE MULTIDISCIPLINARY CHARACTER OF ENGINEERING

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Using Research to Educate Freshman Engineers and High School Students About the Multidisciplinary Character of Engineering

Introduction

Approximately 62% of the undergraduate students who graduated in 2000 with an engineering B.S. in the United States received their degree from Research I and II institutions. [1] Although these universities successfully recruit their undergraduates by proudly displaying their research infrastructure and state-of-the-art facilities, a vast majority of these students graduate without ever being exposed to these assets. Even those students who are introduced to research often remain oblivious to the rich research diversity and the multi-disciplinary culture of engineering. This is an increasingly important concern because the future engineer is expected to adapt to a varying and continuously evolving environment while simultaneously being able to operate outside the narrow limits of one discipline, crossing over boundaries and interfacing between different fields. In recent years, the Boyer Commission,[1] the National Science Foundation,[2] the American Association for the Advancement of Science,[3] and the National Research Council[4] have urged universities to "make research-based learning the standard" for undergraduate education. Participation in research deepens a student's understanding and promotes the communication and teamwork needed to solve complex problems. Enabling students to be part of the intellectual process instills in them a sense of fulfillment and imparts life-long benefits. A report, released on June 2005 by the National Academy of Engineering, further supports these arguments.[5] The report considered current engineering education inadequate to prepare future engineers and suggested that BS graduates should be considered engineers in training and an MS should be a professional degree. This finding illustrates the need at the undergraduate level for "research based learning" which is inherent in the graduate level but almost non-existent in the undergraduate level.

To achieve this research based learning at the undergraduate level, a new educational paradigm is needed that demands a commitment to the intellectual growth of individual students, redefines the role of engineering in society, and stimulates students to pursue careers in engineering and research. These goals can be accomplished by integrating research into engineering education, serving to increase recruitment and retention, and enabling future engineers to become society leaders. To pursue these goals, we have initiated an effort to translate state-of-the-art research to the classroom by bridging the gap between research and education in a way that will reinvent and energize the classroom environment and motivate the students to become lifelong learners and contributors to societal needs through engineering practice.

In this effort, we have placed particular emphasis on transferring research to groups underrepresented in engineering. This effort also encourages the students to engage in hands-on research. The progression of research transfer through the different levels of engineering education is illustrated in **Figure 1**. At the end of this development ladder, we find the future, interdisciplinary engineers who are leaders in industry, technology, and academia. In this effort, via research transfer and examples, another goal is the recruitment of middle school and high school students and the retention of freshman engineers. Recruiting and retention can be increased by creating awareness and improving the image and perceptions of engineering during the early educational stages. This goal will be accomplished by navigating the students through the maze of engineering fields using as "icons" visual and experiential stimulations, adopted from every-day examples that are related to observations in nature or research applications.

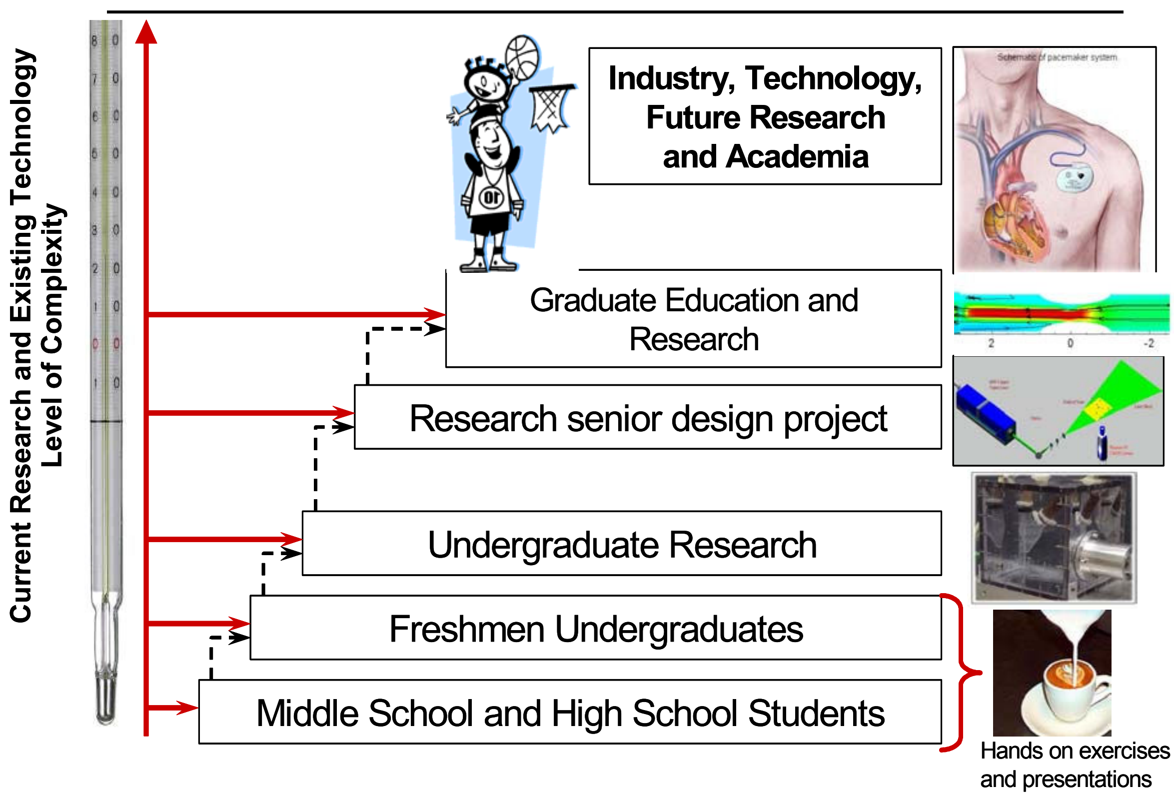


Figure 1. Schematic of the development ladder of research translation to engineering education from middle school to graduate education. This illustration shows the big picture of research transfer leading to interdisciplinary engineers who are leaders in industry, technology, and academia.

As a part of this effort, we attempted to transfer state-of-the-art fluid mechanics and biofluids research into the engineering education of students from the high school level to the undergraduate level. This paper describes what mean by this transfer, discusses our methods to perform and assess the transfer, and presents the transfer's results.

Background: What We Mean by Research Transfer

This paper presents the transfer of recent interdisciplinary engineering research in fluid mechanics and cardiovascular mechanics to the high school and undergraduate classroom in order to meet the following specific aims:

Specific Aim 1: Give students the opportunity to explore the diversity of engineering fields by using tangible and intuitive examples and integrating them with contemporary research applications. For instance, in a presentation about the research to the students, we included several examples such as the one in the slide shown in **Figure 2**.

Specific Aim 2: Demonstrate how seemingly diverse areas of research are connected through the same fundamental engineering principles and how these very same principles apply and govern our every day reality.

Specific Aim 3: Inspire the students to pursue a career in engineering and research, thus supporting student recruitment into engineering (for high school students and undecided undergraduates) or into graduate school (for undergraduates). This aim also supports retention.

Our expectations are that our research transfer will have the following effects on the students:(1) the student's intuition should be sharpened, and (2) the student's perception about engineering should be altered. By improving the high school student's ability to experience and interpret his or her physical environment, undecided high school students might be motivated to purse a career in engineering. Likewise, the undergraduate engineers might be stimulated to engage in undergraduate research and potentially transition towards graduate studies.

The flow of milk into a cup of coffee is similar to the flow of blood into the heart

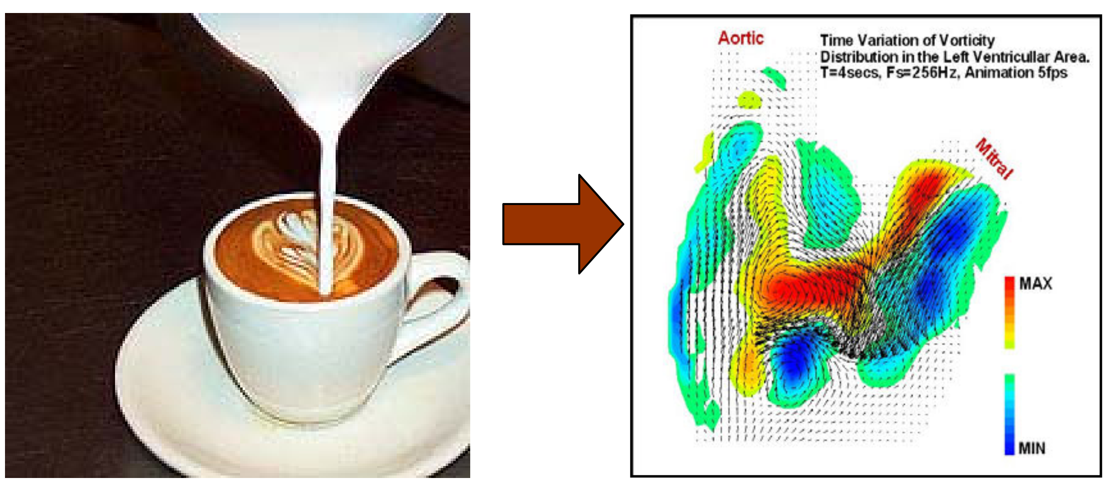


Figure 2. Sample slide included in the research transfer presentation to the students. This slide's purpose was to link the flow characteristics of milk being poured into a cup of coffee to the flow inside the left ventricle past heart valves.

The research was transferred through a series of presentations and hands-on exercises delivered to students participating in ongoing programs sponsored by the Center for the

Enhancement for Engineering Diversity (CEED) at Virginia Tech. The four CEED groups targeted in this effort were as follows:

Computers and Technology at Virginia Tech (C-Tech²) is a two-week summer camp targeting high school girls. The purpose of the program is to introduce participants to engineering and related technologies through various hands-on activities, laboratories, and presentations.

Student Transition Engineering Program (STEP) is a five-week orientation program for new students entering Virginia Tech's College of Engineering. Students participate in an intensive academic program during the summer prior to their freshman year.

Hypatia, a learning community for first-year women engineering students, is a program designed to bring together students in a residential environment to provide encouragement and support in their pursuit of a career in engineering.

Galileo, a learning community for men in engineering, is a program designed to incorporate similar aspects of Hypatia, but with a focus toward issues that male engineers face in the growing competitive marketplace.

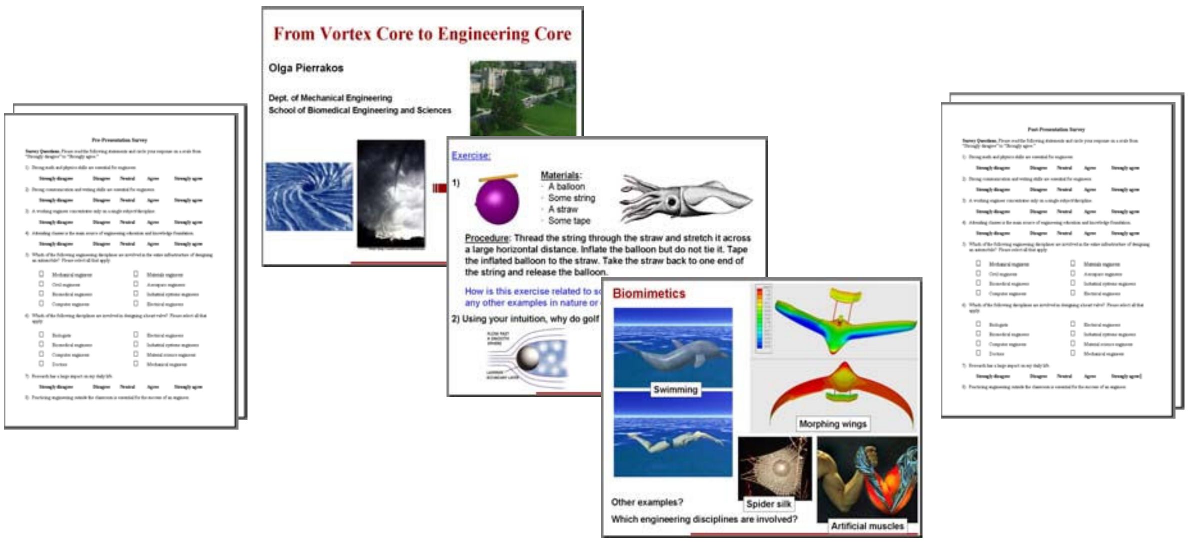
Approximately 310 students participated in these four programs over the summer and fall semesters of 2005. For the purpose of our study, the Hypatia and Galileo groups were considered as one large group since both student groups were at the same educational level and both experienced the research model at the same time. **Table 1** illustrates the student population in terms of gender and race.

Table 1: Student population for the three student groups based on gender and race.

Student Population (Gender and Race)	**C-Tech²**	**STEP**	**Hypatia and Galileo**
Number of Participants	28	53	230
Female	100 %	30 %	30 %
Male	0 %	70 %	70 %
African American	16 %	14 %	4 %
Asian	4 %	6 %	9 %
Caucasian	56 %	68 %	82 %
Hispanic	12 %	4 %	2 %
Other	12 %	8 %	3 %

Methods

As shown in **Figure** 3, the transfer of the research was implemented in three steps: pre-assessment, presentation and demonstrations, post-assessment. The pre- and post-assessments are discussed in more detail in the following section. The seminar-style presentation, which was approximately 90-minutes and was designed to meet Bloom's taxonomy of low-level learning objectives, was given to the CEED students and designed so as to be easily adapted to the dynamics and knowledge base of the different student groups while demonstrating how the same basic principles apply to different fields. The presentation, demonstrations, and exercises were designed to do the following: (1) to explore the diversity of fluids and biomedical engineering fields by using tangible and intuitive real life examples and integrating them with contemporary research; and (2) to demonstrate how seemingly diverse areas of research are connected through fundamental engineering principles and how these principles occur in everyday physical or technological processes. For example, **Figure 4** shows a left-ventricular assist device used to support patients awaiting heart transplantation and a typical jet engine. The grouping of these two examples illustrates how the concept of a fan/compressor is as applicable to aeronautics as it is to bioengineering.



Pre Assessment

Presentation (Engineering Diversity)

Demonstrations/Exercises

Hot Areas of Research for Engineers

Post Assessment

Figure 3. Schematic of the research transfer experience for the CEED groups. The structure of this experience included a pre-assessment survey, a 90-minute presentation which included demonstrations and exercises as well as descriptions and examples of a broad range of research areas, followed by a post-assessment survey.

Upon completion of the presentation and demonstration, our objectives were for the students to be able to *(a)* articulate and recognize the role and importance of engineering in society, *(b)* identify physical mechanisms and phenomena relevant to various simple everyday applications, *(c)* appreciate the interdisciplinary and multidisciplinary character of modern engineering, and *(d)* develop awareness of emerging engineering fields and of future research trends and challenges.

Furthermore, the specific objectives varied for each group of students considering each group's educational level. For the freshmen engineers, the main objective was to introduce them to various research areas as a means of illustrating the diversity of research and the overlap of fundamental engineering concepts. In the case of the high school students and incoming freshmen engineers, research applications were used to educate the students about the following: (1) what engineering is and what the various disciplines are, (2) what process is involved in becoming an engineer, (3) what are some stereotypes of engineers, and (4) the use of research to link the various disciplines.

As mentioned, the goal of this research transfer was to aspire and motivate students to pursue a career in engineering and research, thus supporting student recruitment and retention. Exploring a variety of engineering applications and their impact to society will improve the student's perception of engineering and illustrate the strong effects that engineering research and technology have on our everyday life.

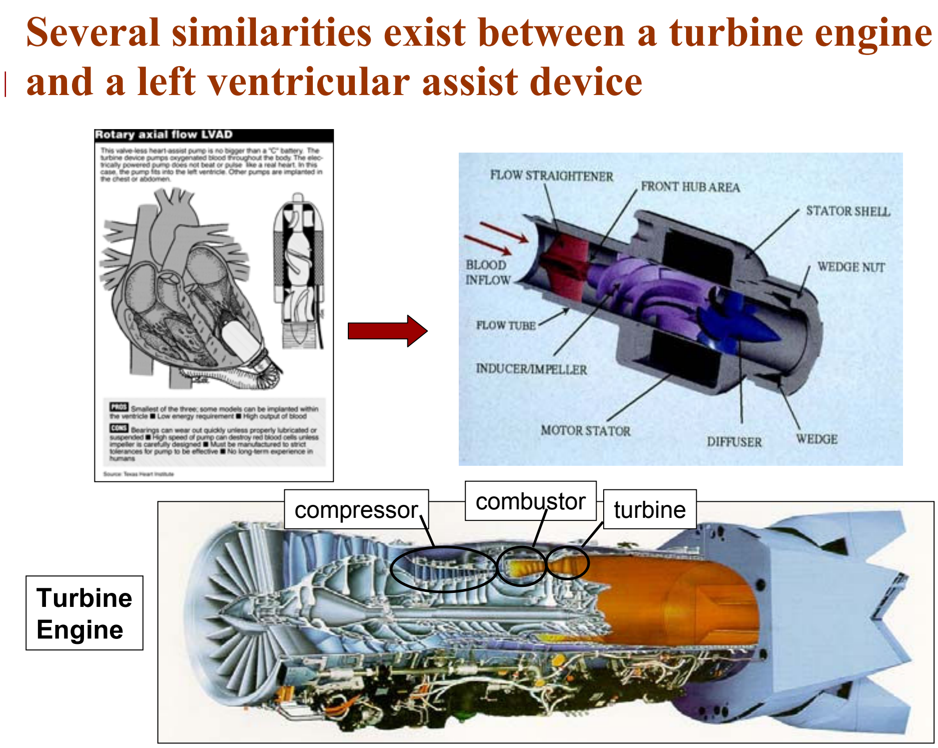


Figure 4. Sample presentation slide illustrating the similarities of a turbine engine and a left ventricular assist device. The slide serves to illustrate how seemingly diverse areas of research are connected through fundamental engineering principles (fan/compressor is as applicable to aerodynamics as it is to bioengineering).

Results and Discussion

The assessment of the research transfer was done by use of pre- and post-surveys, which compared the student's perceptions of engineering stereotypes, research, and discipline diversity. The pre-assessment involved a component to establish the student's knowledge base and background, while the post-assessment included feedback and an overall evaluation of the experience.

For each of the CEED groups, the assessment survey was tailored to meet the objectives of the group and thus varied among the high school, incoming freshmen, and freshmen engineers. The questionnaires were designed to allow derivation of quantitative metrics for the success of the effort. Most of the survey questions were based on a scale of 1 (strongly disagree) to 5 (strongly agree) so that we could quantify the results. Several qualitative-based questions were also included in the surveys in order to more clearly assess what the students' knowledge gain and overall likes/dislikes of the experience were. The pre- and post-surveys were approved by the Virginia Tech Institutional Review Board (IRB) of the Office of Research Compliance.

As mentioned, the specific objectives varied for each group of students considering each group's educational level. For this reason, the assessment surveys also varied as did the results for each group. The results are therefore broken up into two sections, one corresponding to C-Tech^2 and STEP students, with the second to the Hypatia and Galileo students.

Results for C-Tech^2 and STEP Students

This section presents results from selected questions from the pre-and post-surveys for the high school women and incoming freshman engineers (C-Tech^2 and STEP). Initially, in the surveys of these groups of students, we wanted to get a measure of how the students perceived engineering and some of the stereotypes associated with the profession. **Table 2** shows the results for a series of questions pertinent to this assessment. The survey questions were based on a scale of 1 (strongly disagree) to 5 (strongly agree) and the average value is presented in the table. Percent differences between the pre and post results are also reported.

Starting with the high school women, the questions showing the largest impact were the ones in which the students were asked to assess engineering from the following perspectives (percent difference in parentheses): whether "engineers spend much time working alone" (22.8 %), whether "engineering has a large impact on my daily life" (11.1 %), whether "engineers need to be good at communicating" (18.6 %), whether "engineers do boring things" (17.2 %), and whether "engineers spend a lot of time working in groups" (12.9 %). These results show that the high school women had some preconceived stereotypes about engineers and the profession. Therefore, the research model experience and specifically the use of research to teach the students about various engineering disciplines aided in altering and reshaping their stereotypes of engineers and further illustrating engineers in more positive scenarios.

Another very interesting finding about the C-Tech^2 group was when the female students were asked during the research presentation if they personally knew any engineers. The response to this question was written on note cards and the assessment showed that 57% of the female students answered with “yes”. Most of the responses showed that the engineer whom they knew was a father, an uncle, a brother, or other relative. This finding illustrates that many women showing interest and pursuing engineering enter the field because they know an engineer and thus have some exposure to the profession.

The results of **Table 2** for the incoming freshman engineers (STEP) did not show as large of an overall impact as was the case for the C-Tech^2 students. However, the questions showing the largest impact were as follows (percent difference in parentheses): whether “engineers spend much time working alone” (13.8 %), whether “engineers are interesting people” (8.2 %), and whether “engineering has a large impact on my daily life” (8.1 %). These results, compared with the results from the C-Tech^2 students, illustrate that the STEP group students have a better knowledge of engineering, as we would expect. Additionally, when the STEP students (70% male and 30% female—**Table 1**) were asked if they personally know any engineers, 72% of the students answered with a “yes”. Once again, the majority of these students stated that the engineer they personally knew was a father, an uncle, a brother, a relative, and combinations of these. This finding reveals that for male students, as was the case for the female students also, that knowing an engineer personally may be a large influence for the student to pursue engineering.

Table 2: Student survey questions and results pertaining to engineering stereotypes.

Survey Question (Scale of 1 to 5)	**C-Tech^2**			**STEP**		
	Pre	**Post**	**Diff**	**Pre**	**Post**	**Diff**
1 Engineers need to be good at math and science	4.36	4.61	**5.7%**	4.72	4.82	**2.1%**
2 Engineers spend much time working alone	2.50	1.93	**22.8%**	2.89	2.49	**13.8%**
3 Engineers are interesting people	3.96	4.30	**8.6%**	3.77	4.08	**8.2%**
4 Engineering has a large impact on my daily life	4.41	4.90	**11.1%**	4.55	4.92	**8.1%**
5 Engineers need to be good at communicating	4.04	4.79	**18.6%**	4.42	4.53	**2.5%**
6 Engineers do boring things	1.86	1.54	**17.2%**	2.06	2.00	**2.9%**
7 Engineers spend a lot of time working in groups with other people	3.89	4.39	**12.9%**	4.17	4.37	**4.8%**

Furthermore, a series of True/False/Don’t Know questions that were included in the pre and post surveys are presented in **Table 3**. This type of questions was incorporated in order to get a measure of the students’ knowledge gained on the issues of engineering diversity and its multi-disciplinary nature. More specifically, because most people associate mechanical engineers with automobiles, aerospace engineers with airplanes, civil engineers with bridges, and so forth, we wanted to see whether the use of research examples will influence the students to more clearly see the larger picture of engineering—that is, the diversity and multi-disciplinary nature of the profession and the engineering disciplines. In Table 3, the percentages of students answering True (T), False (F), and Don't Know (DK) for each question are shown as well as the percentage differences comparing the pre and post results for C-Tech^2 and STEP.

For the C-Tech^2 students, almost all of the survey statements of **Table 3** revealed high percentage differences especially for statements 2, 3 and 4. Moreover, the results also show that a high percentage of the high school women simply "Didn't Know" if the statement was true or false. This is especially the case for statements 2, 3, and 4, which show that respectively 29 %, 32 %, and 21 % of the C-Tech^2 students answered "Don't Know" in the pre-survey. After the 'research and engineering' presentation, though, the students clearly showed that they knew how to answer the statements correctly. Thus, the students illustrated a better understanding of engineering diversity. On the other hand, for the STEP students, the results of Table 3 reveal that the statement they were unsure of was 5 pertaining to biomedical engineers. Overall, though, the results show that the students of STEP had a better understanding of engineering diversity.

Table 3: Student True/False/Don't Know questions and results pertaining to the diversity and multi-disciplinary character of various engineering disciplines.

	True (T)/False (F)/ Don't Know (DK) Survey Statement	**C-Tech^2**				**STEP**			
			Pre	**Post**	**Diff**		**Pre**	**Post**	**Diff**
1	Engineers work with engineers of the same discipline only	**T**	4%	0%	**-4%**	**T**	0%	2%	**2%**
		F	89%	100%	**11%**	**F**	100%	98%	**-2%**
		DK	7%	0%	**-7%**	**DK**	0%	0%	**0%**
2	Aerospace engineers have nothing in common with mechanical engineers	**T**	0%	4%	**4%**	**T**	2%	2%	**0%**
		F	71%	93%	**21%**	**F**	98%	98%	**0%**
		DK	29%	4%	**-25%**	**DK**	0%	0%	**0%**
3	Only civil engineers are involved in designing bridges	**T**	7%	7%	**0%**	**T**	8%	2%	**-6%**
		F	61%	86%	**25%**	**F**	90%	98%	**8%**
		DK	32%	7%	**-25%**	**DK**	2%	0%	**-2%**
4	Biomedical engineers design artificial organs and implantable devices	**T**	79%	93%	**14%**	**T**	80%	94%	**14%**
		F	0%	7%	**7%**	**F**	4%	4%	**0%**
		DK	21%	0%	**-21%**	**DK**	16%	2%	**-14%**

Results for Hypatia and Galileo Students

The assessments for the first semester freshman engineers (Hypatia and Galileo groups) focused more on their background, knowledge and appreciation of research in their undergraduate engineering education. Although not presented here, assessment results showed that their background of engineering and the various disciplines was similar to the STEP group discussed previously. For this group of students, our main goal was to use engineering research examples as a means of giving the students a different perspective of engineering applications and problem solving and certainly to illustrate how seemingly diverse disciplines of engineering are intertwined. It was also important to illustrate the impact of engineering research in the student's daily life. **Table 4** shows selected survey questions tailored to quantify these goals for this student group. The questions were based on a scale of 1 to 5 (strongly disagree to strongly agree). Both mean results and actual percentages for each scale are presented in accompaniment with percent differences between pre and post surveys.

Table 4: Student survey questions and results pertaining to knowledge of engineering diversity and research.

	Survey Question (Scale of 1 to 5)	Strongly Disagree (SD) - 1 Disagree (D) - 2 Neutral (N) - 3 Agree (A) - 4 Strongly Agree (SA) - 5	**Hypatia/Galileo**			
			Scale	**Pre**	**Post**	**Diff**
		Mean Values	**1** (SD)	1.8 %	1.8 %	**0 %**
		Pre 3.65	**2** (D)	9.4 %	7.1 %	**-2.2 %**
1	Research has a large impact on my daily life	Post 3.96	**3** (N)	30.8 %	15.2 %	**-15.6 %**
			4 (A)	38.4 %	45.5 %	**7.1 %**
		Diff 8.4%	**5** (SA)	19.6 %	30.4 %	**10.7 %**
		Mean Values	**1** (SD)	0.9 %	1.8 %	**0.9 %**
		Pre 4.19	**2** (D)	2.2 %	1.8 %	**-0.4 %**
2	Research is as important to engineering as it is to science	Post 4.26	**3** (N)	7.6 %	7.1 %	**-0.4 %**
			4 (A)	55.8 %	47.3 %	**-8.5 %**
		Diff 1.7%	**5** (SA)	33.5 %	42.0 %	**8.5 %**
		Mean Values	**1** (SD)	0.9 %	0.9 %	**0 %**
		Pre 3.77	**2** (D)	4.9 %	4.5 %	**-0.4 %**
3	Participating in engineering research is essential for an undergraduate's engineering education	Post 3.98	**3** (N)	28.1 %	17.9 %	**-10.3 %**
			4 (A)	48.7 %	49.6 %	**0.9 %**
		Diff 5.6%	**5** (SA)	17.4 %	27.2 %	**9.8 %**

Statement 1 of Table 4 shows one of the highest values of impact. Specifically, statement 1 ("Research has a large impact on my daily life") showed that approximately 18% more students answered "Agree" and "Strongly Agree" in the post-survey after the research presentation. It is also important to note that 30.8% of the students initially answered statement 1 with "Neutral", whereas the post-survey showed that half of those students changed their response to "Agree" and "Strongly Agree". This observation may imply that many of the students simply didn't know the value of research on their daily life and thus responded with a "Neutral".

Statement 2 ("Research is as important to engineering as it is to science") also revealed that the majority of the students, approximately 89%, in both the pre and post surveys either "Agreed" or "Strongly Agreed" with the statement. Yet, from these students, approximately

8.5% changed from "Agree" to "Strongly Agree", thus illustrating that they feel more strongly about the value of engineering research after the presentation.

Lastly, approximately 10% more students "Strongly Agreed" with statement 3 ("Participating in engineering research is essential for an undergraduate's engineering education") in the post-survey and the results showed that 77% of the students either "Agreed" or "Strongly Agreed" to research being an essential component of undergraduate education.

Overall Results of Research Transfer

A second type of assessment of the research model was based on how valuable the students rated the experience. This assessment was based on three quantitative and a couple qualitative survey questions included on the post-survey. **Figure 5** shows the results of the three quantitative questions, which were based on a scale of 1 to 5 (strongly disagree to strongly agree), for all the groups. Almost all of the results show mean values of at least 4. This finding illustrates that overall the effort has much promise as a model for transferring engineering research to the high school and undergraduate levels. Moreover, more detailed assessment of the questions of Figure 5 (that is, "Overall, this presentation was a valuable learning experience," "This presentation was valuable for learning about the diversity of engineering," and "This experience gave me a clear picture of the relevance of engineering research") show that the C-Tech^2 and STEP groups responded with higher ratings for the experience. This observation might illustrate that the research model was more influential and highly valued by these group of students because of the more knowledge gained.

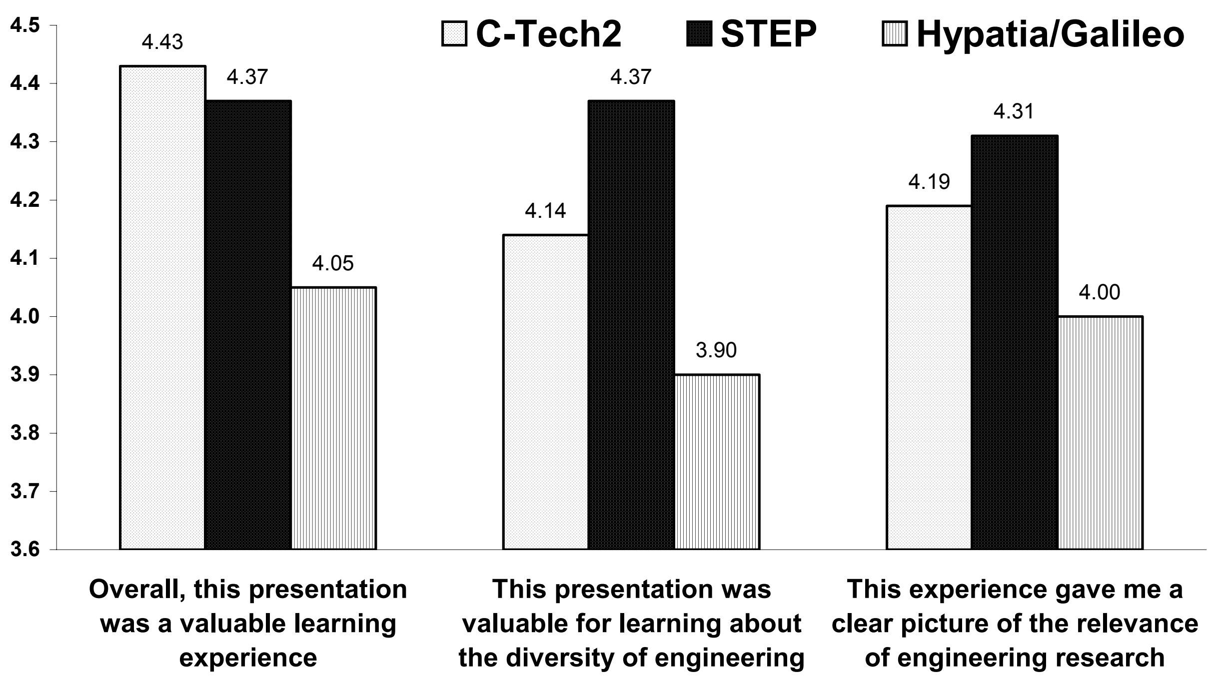


Figure 5. Student survey questions and results pertaining to the value of the research transfer.

As for the qualitative survey questions (that is, "how would you describe this experience?", "what appealed to you most during this experience?", and "what appealed to you least during this experience"), similar results were observed. More specifically, the majority of the students found the experience informative, interesting, and resourceful. In particular, the students enjoyed the short demonstrations, exercises, short videos of research examples, and the visuals. The biggest complaint about the experience was the duration which was about an hour and a half.

Lastly, the students were asked to rate if engineering is the profession they want to pursue. In particular, the high school students and incoming freshman (C-Tech^2 and STEP) were asked the following: "I would consider a career in engineering". For the C-Tech^2 students, the percentage of students that answered either "Agree" or "Strongly Agree" was 80% in the pre-survey and 86% in the post-survey. For the same survey question, the percentage of STEP students that answered either "Agree" or "Strongly Agree" was 85% in the pre-survey and 90% in the post-survey.

As for the Hypatia and Galileo students, who are considered freshman engineering students, the question was tailored to the following form: "I am confident about my decision to pursue engineering for my undergraduate degree". The results showed that the percentage of students which answered either "Agree" or "Strongly Agree" was 84% in the pre-survey and 89% in the post-survey. In addition, this group of students was also asked whether they "plan on pursuing a Master's degree" and "plan on pursuing a Ph.D. degree". For these two statements, the percentage of students that answered either "Agree" or "Strongly Agree" was approximately 54% (for pursuing a Master's) and 15% (for pursuing a PhD) in the pre-survey and respectively 60% and 18% in the post-survey. These findings show that after the research presentation, 6% more students were likely to pursue a Master's and 3% more students to pursue a PhD in engineering.

Conclusions

This paper has presented and evaluated the transfer for state-of-the-art fluid mechanics and biofluids research into the engineering education of students from the high school level to the undergraduate level. For the undergraduates, the goal was to introduce them to various research areas as a means of illustrating the diversity of research and the overlap of fundamental engineering concepts. In the case of the high school students and incoming freshman engineers, research applications were used to educate the students about what engineering is and the various disciplines, about the process involved to become an engineer, some of the stereotypes of engineers, and use of research to link the various disciplines. Overall, the findings illustrate that the effort has much promise as a model for transferring engineering research to the high school and undergraduate levels.

For the high school women (C-Tech^2), significant differences (6-25%) were observed when comparing the pre- and post-results when students were asked to assess engineering. The results showed that the high school women had some preconceived stereotypes about engineers and the profession. Therefore, the research model experience and specifically the use of research to teach the students about various engineering disciplines aided in altering and reshaping their stereotypes of engineers and further illustrating engineers in more positive scenarios. For the pre-college students, differences on the order of 2-18% were found. These results, compared with the results from the C-Tech^2 students, illustrate that the STEP group students have a better knowledge of engineering, as we would expect.

After the 'research and engineering' presentation, results also showed that the students illustrated a better understanding of engineering diversity and the multi-disciplinary nature of engineering. Additionally, when the students were asked to rate if engineering is the profession they want to pursue, 6% more C-Tech^2 students and 5% more STEP students were agreed with the statement in the post-survey. Another interesting observation was when the students were asked if they personally know any engineers, 57% of the C-Tech^2 students and 72% of the STEP students answered with a "yes". This finding reveals that, for both the female and male students, knowing an engineer personally may be a large influence for the student to pursue engineering.

The assessment for the first semester freshman engineers (Hypatia and Galileo) focused more on their knowledge and appreciation of research (showing approximately an 8-10% increase from the pre- to the post-results) and its impact in their daily life and in their undergraduate engineering education. Results show that after the research presentation, 6% more students were likely to pursue a Master's and 3% more students to pursue a PhD in engineering.

One broader impact of the proposed experience is that the students who go through the program will have a better awareness of engineering and the future direction engineering is taking as a profession. A positive research experience can be critical to a student's decision about graduate education. This effort, which should significantly improve the students' image of what is engineering, should also deepen their appreciation of research and graduate studies as a career path, thus resulting in more graduate students who may also be more open to working with undergraduates because of the benefits they earned. A second broader impact is that the proof-of-concept course will have underrepresented groups in engineering make up at least forty percent of the participants. Yet a third broader impact is that the experience should serve to inform and promote other undergraduates about the value and opportunity of undergraduate research experiences. Finally, a fourth broader impact is that should this course prove successful at enriching and promoting undergraduate research, the structure of this course should readily transfer to other schools. In other words, the technical communication courses at many schools would have a few sections designated as having a summer research option a structure. The ultimate measure of this success, though, will be the likelihood of these students to pursue engineering, participate in research as undergraduates, and even pursue graduate degrees.

Acknowledgments

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References

[1] Boyer Commission on Education of Undergraduates in the Research University, Reinventing Undergraduate Education: A Blueprint for America's Research Universities (New York: 1998).

[2] National Science Foundation, New Expectation for Undergraduate Education in Science, Mathematics, Engineering, and Technology (Washington, DC: NSF Directorate for Education and Human Resources, June 1996), pp.ii, 2, 4, 21, 41, 51, 65.

[3] American Association for the Advancement of Science, Project 2061 Update (Washington, DC: AAAS, 2001-2002).

[4] National Research Council, Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics (Washington, DC: National Research Council, 2003), p. 116.

[5] National Academy of Engineering of the National Academies, "Education the Engineer for 2020: Adapting Engineering Education to the New Century," The National Academies Press: Washington, D.C., 2005.