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Exploration of Multi-layered Mentorship Approaches in Summer Engineering Programs

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Abstract
The purpose of this study was to examine the influence of multi-layered mentoring in summer engineering programs on confidence in understanding engineering research, engineering disciplines and the ability to conduct engineering research. This paper describes the work in progress towards incorporating this approach into summer programs at Rutgers University. The participants in the study included high school students from over 6 different high schools in New Jersey, coupled with in-service teachers who were participants in a National Science Foundation RET Site: Rutgers University Research Experience for Teachers in Engineering for Green Energy Technology and undergraduate scholars who participated in the REU Site: Green Energy Technology Undergraduate Program. The perceptions, understanding and evaluation of the program before the implementation of the multi-layered mentorship program are compared to the multi-layered program. High school students expressed higher confidence levels in the engineering design cycle and knowledge of the engineering discipline in the multi-layered mentorship program. Undergraduate students who were in labs where they peer-mentored teachers expressed higher levels of confidence in their skills as researchers than undergraduate students who did not peer-mentor in-service teachers or high school students. Future work will include enhanced data sampling, a revision of interview questions and assessment of participant's understanding of concepts via quizzes.

I. Introduction

Over the past several decades mentorship programs within industrial, collegiate and K-12 professional and educational environments have been of intense interest. For example, [1-4] found that undergraduate students and *in particular women and underrepresented minority students reported increased skills, confidence and motivation to pursue science or engineering* careers as a result of research experiences and positive relationships with mentors. In fact, women and under-represented minorities are less likely to enter and remain in science and engineering when they do not have access to mentors and role models [3-5]. Also, [6, 7] found that *near-peer mentoring* enhances learning and understanding of core technical content and provides leadership opportunities for graduate and undergraduate students who mentor middle and high school students. Opportunities such as these, "*provide a visual pathway for younger students to envision themselves as future scientists* [6]." These prior works are the motivation for the multi-layered mentorship case study that included K-12 teachers, graduate, undergraduate and high school students during multiple summer engineering research experiences. The participants in the study included high school students from over 6 different high schools in New Jersey, in-service teachers who were participants in a National Science Foundation RET Site: Rutgers University Research Experience for Teachers in Engineering for Green Energy Technology[8, 9] and undergraduate scholars who participated in the REU Site: Green Energy Technology Undergraduate Program[10]. Undergraduate and graduate students from Rutgers also participated in this study.

The purpose of this work is to discuss the work in progress of a case study that was designed to address two research questions:

1. Would undergraduate students who peer-mentored teachers or high school students express higher levels of confidence in their engineering research skills than those who did not peer-mentor teachers or high school students?

2. Would the high school students' confidence in their knowledge of engineering disciplines and the engineering design cycle differ depending on the engagement of teachers and undergraduate students in their respective labs?

II. Overview of the Partnering Summer Research Programs

The in-service teachers and undergraduate student participants in this study were from summer programs funded by the National Science Foundation. The motivations for the summer programs are to address the United States' need for environmentally friendly power [11] and for all three programs to enrich the population of STEM professionals that are prepared to tackle the technical challenges of national need. The intellectual foci of summer program for the teachers and the undergraduate research program are: nanotechnology and materials, renewable and sustainable fuels, and devices and energy management systems for civil structures, energy generation, conversion, and storage.

II.1. *Research Experience for Teachers Summer Program*

The summer program for the teachers is a non-residential program that brings K-12 math, science and pre-engineering teachers to a college campus to engage in an authentic engineering research experience for 6 weeks in the summer beginning from the last week in June and ending the first week in August. During their time on the college campus teachers spend 80% of their time in the laboratory. Teachers spent the remaining time engaged in engineering and science-related seminars, field trips, training on operation of research related equipment, rigorous preparation and evaluation of curricular units, and participation in events aimed at developing teacher-faculty interaction and teacher-teacher communication.

II.2. *Undergraduate Research Program*

The undergraduate research program is a residential summer program that engages undergraduate rising juniors and seniors in innovative "green" science and engineering research during a 10-week summer program and provides these scholars with professional development and academic training and exposure to cutting edge research equipment and facilities, where the program was designed to foster undergraduates' understanding of and self-efficacy in science and engineering. Students who participated in the program arrived to campus during the last week in May and the program ended in the first week in August.

II.3 *High School Summer Program*

The high school summer academy is a non-residential summer program house in the Mechanical and Aerospace Engineering Department called *Student Learning and Achievement in Aerospace and Mechanical (SLAAM) Engineering[12]*, that was developed to expose academically talented and motivated high school students to the engineering design process and the diversity of research topics available within the Mechanical and Aerospace Engineering Department. This program provides opportunities for students during three two-week sessions during the summer, where the first session typically begins in the first week of July and the last session ends in the second week of August.

III. Research Design

A mixed method research approach was implemented to gain an understanding of the two research questions. All three groups of participants were given pre- and post-surveys that were based on differential Likert-type scales. The survey questions are provided in the Appendix. In addition, the undergraduate students and teachers participated in individual group interviews, while the high school fellows participated in group interviews (only). The qualitative aspect of the program interviews was performed to assure the validity the survey instrument used. A summary of some of the interview questions is provided in the Appendix.

The study included fourteen research labs. The lab assignments were categorized according to six different subgroups:

- Three laboratories housed undergraduates and high school students.
- Three laboratories housed *only* high school students.
- Two laboratories housed *only* undergraduate students
- Two laboratories housed in-service teacher fellows, undergraduate and high school students.
- Two laboratories housed in-service teacher fellows and undergraduate students.
- Two laboratories housed *only* in-service teacher fellows.

All labs had graduate student and faculty mentors for all participants. All labs included participants in weekly or bi-weekly research group meetings. The undergraduate student fellows were not responsible with the sole responsibility of mentoring and training high school fellows or teachers. Instead, the undergraduate participants provided guidance and insight where appropriate as the high school fellows and teachers worked on projects related to those of the undergraduate student fellows. The undergraduate students arrived to campus prior to the high school students and teachers, thus enabling them to gain more insight pertaining to the research project and research environment.

Teachers and high school students were given pre and post surveys that asked them to rate their confidence in knowledge about the engineering design process, ability to conduct engineering research and types of engineering disciplines. Undergraduate students were asked to rank their level of confidence in conducting engineering research.

Paired T tests were performed on the pre- and post- survey responses of the participants to determine the significance of the mean responses. Two-sample T tests for data sets with unequal variances were performed to examine the differences between high school and undergraduate students who were housed in the six different laboratory subgroups defined previously. All T tests were run with an alpha level equal to 5% and two-tailed assumptions.

IV. Preliminary Results and Discussion

IV.1. *Demographics of the Participants*

The demographic information for the participating high school students, undergraduate students and in-service teachers is provided in Table 1 through Table 6. These tables show that over 50% of the high students who participated in the study were male and Asian, while over 60% of the undergraduate scholars who participated as near-peer mentors for the high school students and teachers were demographically from under-represented groups, i.e. either Latin or African American. And, the number of male and female undergraduate scholars were equal in representation in this study. The demographics of the teachers are notably different than those of the other two groups, where over 86% of the in-service teachers were Caucasian and 60% were women.

Table 1: Racial and ethnic demographics of the high school students who participated in the study.

	Number of Students	Percentage of the High School Student Population
Black/African American	3	10.3
Latino/Hispanic	3	10.3
Asian	16	55.2
Pacific Islander	1	3.4
Caucasian	5	17.2
Other	1	3.4
Total	29	100.0

Table 2: Gender representation of the high school participants.

	Number of High School Students	Percentage of the High School Population of Participants
Female	9	31.0
Male	20	69.0
Total	29	100.0

Table 3: Demographics of the undergraduate participants in terms of gender.

	Number of Undergraduate Students	Percentage of the Undergraduate Population of Participants
Male	6	50.0
Female	6	50.0
Total	12	100.0

Table 4: Demographic demographics of the undergraduate participants as a function of race and ethnicity.

	Number of Undergraduate Students	Percentage of the Undergraduate Population of Participants
African American	3	25.0
Asian	3	25.0
Caucasian	1	8.3
Latino	5	41.7
Total	12	100.0

Table 5: Gender demographics of the in-service teachers who participated in the summer research program.

	Number of In-service Teachers	Percentage of the In-Service Teacher Population of Participants
Male	6	40
Female	9	60
Total	15	100

Table 6: Racial demographics of the in-service teachers who participated in the summer research program.

	Number of Undergraduate Students	**Percentage of the Undergraduate Population of Participants**
African American	1	6.67
Asian	1	6.67
Caucasian	13	86.67
Latino	0	0
Total	15	100.00

VI.2. High School Participant Results

The high school students were asked to rank their confidence in mathematical ability, ability to conduct engineering research and knowledge of the engineering design cycle using a Likert scale, e.g. 1 = Definitely Yes, 2 = Probably Yes, 3 = Might or Might Not, 4 = Probably Not, and 5 = Definitely Not. The survey questions posed to the high school students, undergraduate students and teachers are in the Appendix. The mean values for the high school participant responses for the pre-survey are depicted in Table 7 and the post survey results may be found in Table 8. There was a marked increase in the confidence of the high school students resulting from the high school summer program and interaction with the research and student environments as indicated in Table 7 and Table 8. The number of high school students participating in the study is small (29 participants), but enough to calculate statistical averages and standard deviations for the items under investigation. It is also large enough to perform paired two sample T test of the pre- and post-test survey responses of confidence in math skills, ability to conduct engineering research and knowledge of the engineering design cycle. Hence, the results from paired t-test analyses with an $\alpha=0.05$ are presented in *Table 9*, *Table 10* and *Table 11* confirm that these preliminary results indicate statistical significance and the probability of repeatability. Larger sample sizes of male and female participants and more diversity in student race/ethnicity are needed to statistically study differences based on gender in high school student experiences. The difference in t-score for confidence in math skills is the smallest of all of the studies. This is most likely because the high school students who were selected to participate in the program were high achieving high school students who performed well in mathematics according to their high school transcripts. The largest differences in pre and post means are observed for confidence in ability to conduct engineering research and knowledge of the engineering design cycle. This larger difference is most likely due to the exposure of the high school students to research for the first time. This was verified through group interviews with the high school students. Ironically, student who had initially rated their knowledge of the engineering design cycle as a “1” or “2” admitted in the group discussions that they were “surprised by the disciplines that they did not know about” and would have most likely ranked themselves lower in their pre-survey if they had to do it over again. This suggests that some high school students may be more confident in their knowledge of engineering than they are in reality. Further study regarding how students developed their perceptions of knowledge and how to better measure the pre-knowledge via quizzes is an area of proposed future work.

Table 7: High school student responses from a pre-survey regarding confidence in their knowledge of the math, engineering research and the engineering design cycle. The values

presented are the mean scores based on a Likert scale, where 1 = Definitely Yes, 2 = Probably Yes, 3 = Might or Might Not, 4 = Probably Not, and 5 = Definitely Not.

	I am confident in my math skills.	I am confident in my skills to conduct engineering research.	I am confident in my knowledge of the engineering design cycle.
	Mean	Mean	Mean
female	2.11 $\pm$ 0.60	4.22 $\pm$ 0.67	4.00 $\pm$ 0.50
male	2.00 $\pm$ 0.65	4.55 $\pm$ 0.76	3.85 $\pm$ 0.49

Table 8: High school student responses from a post-survey regarding confidence in their knowledge of the engineering design cycle, engineering research and the engineering design cycle. The values presented are the mean scores based on a Likert scale, where 1 = Definitely Yes, 2 = Probably Yes, 3 = Might or Might Not, 4 = Probably Not, and 5 = Definitely Not.

	I am confident in my math skills.	I am confident in my skills to conduct engineering research.	I am confident in my knowledge of the engineering design cycle.
	Mean	Mean	Mean
female	2.00 $\pm$ 0.78	3.33 $\pm$ 0.87	3.11 $\pm$ 0.33
male	1.90 $\pm$ 0.70	3.05 $\pm$ 0.89	2.80 $\pm$ 0.41

Table 9: Results for a paired two sample mean t-test analysis for high school students' perceived confidence in their math skills (comparison of pre- and post-survey data).

	I am confident in my math skills. (Pre-Survey)	I am confident in my math skills. (Post-Survey)
Mean	2.03	1.93
Variance	0.39	0.50
Observations	29.00	29.00
Pearson Correlation	0.82	
Hypothesized Mean Difference	0.00	
Df	28.00	
t Stat	1.36	
P(T<=t) two-tail	0.18	
t Critical two-tail	2.05	

Table 10: Results for a paired two sample mean t-test analysis for high school students' perceived confidence in their ability to conduct engineering research (comparison of pre- and post-survey).

	I am confident in my skills to conduct engineering research. (Pre-survey)	I am confident in my skills to conduct engineering research. (Post-survey)
Mean	4.45	3.14
Variance	0.54	0.77
Observations	29.00	29.00
Pearson Correlation	0.51	
Hypothesized Mean Difference	0.00	
df	28.00	

t Stat	8.75	
P(T<=t) two-tail	1.68E-09	
t Critical two-tail	2.05	

Table 11: Results for a paired two sample mean t-test analysis for high school students' perceived confidence in their knowledge of the engineering design cycle (comparison of pre- and post- survey).

	I am confident in my knowledge of the engineering design cycle. (Pre-survey)	I am confident in my knowledge of the engineering design cycle. (Post-survey)
Mean	3.90	2.90
Variance	0.24	0.17
Observations	29	29
Pearson Correlation	0.48	
Hypothesized Mean Difference	0	
Df	28	
t Stat	11.63	
P(T<=t) two-tail	3.09E-12	
t Critical two-tail	2.05	

VI.3 In-Service Teacher Results

Similarly, teachers were give pre- and post-surveys to examine their perceived confidence in their own knowledge of engineering disciplines, research and the engineering design cycle as shown in *Table 12* and Table 13. Though the number of in-service teachers participating in the study was small, a paired two sample T test of the pre- and post-test survey responses was performed to determine if the preliminary results indicated statistical significance and probability of repeatability. The findings from these analyses are provided in Table 14 and Table 15. The results indicated that on average, the female teachers were less confident in their ability to conduct engineering research and their knowledge of the engineering design cycle. This is consistent with other research that has concluded that women in STEM often are less confident in their abilities than their male counterparts who share similar backgrounds and education levels. Three of the teachers in the participants surveyed were engineers who had chosen teaching as a second career. This may have enhanced survey confidence scores in the pre-survey. The confidence of the teachers on average increased by the end of the summer experience, as shown in *Table 13*.

The interviews with the teachers also confirmed the averages shown in the tables, wherein many teachers had never conducted any form of engineering research prior to their experience in the summer engineering program. Also, many of them believed that the engineering design cycle was "the same" as the scientific method, and often taught this to their students. Also, many teachers prior to the program where not aware of the disciplines of engineering and how these areas of study translate into engineering careers, products, and services. During group and individual interviews of teachers, many remarked that they were surprised at how long it took graduate students to work on design engineering experiments, equipment and procedures, where students would often iterate when something did not work as planned. They indicated that they would take these types of experiences back to their classrooms to illustrate to their students the cyclic nature of the engineering design cycle. Interview questions are provided in the Appendix.

Table 12: Teacher responses from a pre-survey regarding confidence in their knowledge of the engineering design cycle and the engineering research and the engineering design cycle. The values presented are the mean scores based on a Likert scale, where 1 = Definitely Yes, 2 = Probably Yes, 3 = Might or Might Not, 4 = Probably Not, and 5 = Definitely Not.

	I am confident in my skills to conduct engineering research. (Pre-survey)	I am confident in my knowledge of the engineering design cycle (Pre-Survey)
	Mean	Mean
female	4.22 ± 0.44	3.11 ± 0.60
Male	3.5 ± 0.75	2.83 ± 0.38

Table 13: Teacher responses from a post-survey regarding confidence in their knowledge of the engineering design cycle and engineering research as a function of gender. The values presented are the mean scores based on a Likert scale, where 1 = Definitely Yes, 2 = Probably Yes, 3 = Might or Might Not, 4 = Probably Not, and 5 = Definitely Not.

	I am confident in my skills to conduct engineering research. (Post-survey)	I am confident in my knowledge of the engineering design cycle (Post-Survey)
	Mean	Mean
female	2.11 ± 0.33	2.67 ± 0.22
Male	1.67 ± 0.69	1.16 ± 0.15

Table 14: Results for a paired two sample mean t-test analysis for teachers' perceived confidence in their ability to conduct (comparison of pre- and post- survey).

	I am confident in my ability to conduct engineering research. (Pre-survey)	I am confident in my ability to conduct engineering research. (Post-survey)
Mean	3.93	1.93
Variance	0.35	0.21
Observations	15	15
Pearson Correlation	0.77	
Hypothesized Mean Difference	0	
df	14	
t Stat	20.49	
P(T<=t) two-tail	7.72E-12	
t Critical two-tail	2.14	

Table 15 Results for a paired two sample mean t-test analysis for teachers' perceived confidence in their knowledge of the engineering design cycle (comparison of pre- and post- survey).

	I am confident in my knowledge of the engineering design cycle (Pre-Survey)	I am confident in my knowledge of the engineering design cycle (Post-Survey)
Mean	3.00	2.07
Variance	0.29	0.78
Observations	15	15
Pearson Correlation	0.30	
Hypothesized Mean Difference	0	
df	14	
t Stat	4.09	
P(T<=t) two-tail	1.10E-03	
t Critical two-tail	2.14	

VI.5. Subgroup Results

In order to determine if the undergraduate students who peer-mentored teachers had higher levels of confidence in their ability to conduct engineering research, two-sample T tests were performed where it was assumed that the data sets had unequal variances. In these studies, the control was the subgroup laboratories that were comprised of only an undergraduate researcher, faculty member and graduate student. The control subgroup results were compared to the average confidence levels of the participant subgroupings. The students were surveyed on a Likert scale, where 1 = Definitely Yes, 2 = Probably Yes, 3 = Might or Might Not, 4 = Probably Not, and 5 = Definitely Not. The average values as a function of laboratory subgrouping is depicted in Table 16. Though the number of undergraduate students participating in the study was small, two sample T test analyses of the post-test survey responses were performed to determine if the preliminary results indicated statistical significance and probability of repeatability. The results from the t-tests are shown in *Table 17*, *Table 18* and *Table 19*. From these results, it appears that laboratories that contained both undergraduates, high school students and teachers rendered more confidence in undergraduate students.

Interviews with participants indicated that undergraduate students who were in laboratories by themselves expressed feelings of being "disconnected". Some students expressed feelings of being intimidated by "what they did not know". Undergraduates who were paired with teachers or high school students expressed feelings of feeling empowered to ask questions when both they and their partner, i.e. teacher or high school student did not understand something. Undergraduates also expressed higher senses of confidence in their abilities when they were able to explain experiments and engineering concepts to teachers and high school students. Several of them noted that they practiced their mid-summer symposium presentations with these groups and were reassured when they were able to answer their questions during dress rehearsals with their laboratory teacher and high school student partners.

Table 16: Undergraduate student responses from a post-survey that asked them to rank their confidence in their ability to conduct engineering research. The values presented are the mean

scores based on a Likert scale, where 1 = Definitely Yes, 2 = Probably Yes, 3 = Might or Might Not, 4 = Probably Not, and 5 = Definitely Not.

	I am confident that I understand how to conduct scientific/engineering research. (Post Survey)
	Mean
UG Only	3.33 + 0.33
HS and UG	2.00 + 0.00
UG and Teachers	2.50 ± 0.50
HS, UG and Teachers	1.33 + 0.33

Table 17: Results for a two sample mean t-test analysis of undergraduate self-confidence in their ability to conduct engineering research. Laboratories that included undergraduate students only are compared with laboratories that included undergraduate and high school students.

	I am confident in my ability to conduct engineering research. (Post-Survey) **Subgroup – UG Only**	I am confident in my ability to conduct engineering research. (Post-Survey) **Subgroup – UG and HS**
Mean	3.33	2.00
Variance	0.33	0.00
Observations	3	4
Hypothesized Mean Difference	0	
Df	2	
t Stat	4.00	
P(T<=t) two-tail	0.06	
t Critical two-tail	4.30	

Table 18: Results for a two sample mean t-test analysis of undergraduate self-confidence in their ability to conduct engineering research. Laboratories that included undergraduate students only are compared with laboratories that included undergraduates and teachers.

	I am confident in my ability to conduct engineering research. (Post-Survey) **Subgroup - UG Only**	I am confident in my ability to conduct engineering research. (Post-Survey) **Subgroup - UG and Teachers**
Mean	3.33	2.50
Variance	0.33	0.50
Observations	3	2
Hypothesized Mean Difference	0	
Df	2	
t Stat	1.39	
P(T<=t) two-tail	0.30	
t Critical two-tail	4.30	

Table 19: Results for a two sample mean t-test analysis of undergraduate self-confidence in their ability to conduct engineering research. Laboratories that included undergraduate students only

are compared with laboratories that included undergraduates, high school students and teachers.

	I am confident in my ability to conduct engineering research. (Post-Survey) **Subgroup - UG Only**	I am confident in my ability to conduct engineering research. (Post-Survey) **Subgroup - UG, HS and Teachers**
Mean	3.33	1.33
Variance	0.33	0.33
Observations	3	3
Hypothesized Mean Difference	0	
Df	4	
t Stat	4.24	
P(T<=t) two-tail	0.01	
t Critical two-tail	2.78	

High school students' confidence in their knowledge of the engineering design cycle, ability to conduct research and knowledge of engineering disciplines, are examined as a function of laboratory subgroup population in Table 20. The results in this table indicate that high school students feel more confident about their knowledge of the engineering design cycle when they were housed in laboratories that included undergraduate students. Two-sample t-test analyses were performed to verify repeatability of the data capture. The number of undergraduate students who participated in the program was small. So, the findings are weakened by the small data sample, but are used here to make preliminary conclusions, which will be examined with continued study in future work.

Table 20: High School student responses from a post-survey regarding confidence in their knowledge of the engineering design cycle, engineering disciplines and confidence in conducting engineering research. The values presented are the mean scores based on a Likert scale, where 1 = Definitely Yes, 2 = Probably Yes, 3 = Might or Might Not, 4 = Probably Not, and 5 = Definitely Not.

	I am confident that I know about the engineering design cycle.	I am confident that I understand how to conduct engineering research.	I am familiar with the different types of engineering disciplines.
	Mean	Mean	Mean
HS and Teachers	2.17 + 0.17	3.17 ± 0.98	2.0
HS and UG	1.29 + 0.24	1.29 ± 0.49	2.0
HS only	2.00 ± 0.67	2.80 ± 0.63	2.8
HS, UG and Teachers	1.67 ± 0.27	2.00 ± 0.63	1.10

Table 21: Results for a two sample mean t-test analysis of high school students self-confidence in their knowledge of the engineering design cycle. Laboratories that included high school students only are compared with laboratories that included undergraduates and high school students.

	I am confident in my knowledge of the engineering design cycle. (Post-Survey) **Subgroup - HS Only**	I am confident in my knowledge of the engineering design cycle. (Post-Survey) **Subgroup - HS & UG**
Mean	2.00	1.29

Variance	0.67	0.24
Observations	10	7
Hypothesized Mean Difference	0.00	
Df	15.00	
t Stat	2.25	
P(T<=t) two-tail	0.04	
t Critical two-tail	2.13	

Table 22: Results for a two sample mean t-test analysis of high school student self-confidence in their ability to conduct engineering research. Laboratories that included high school students only are compared with laboratories that included high school students and teachers.

	I am confident in my knowledge of the engineering design cycle. (Post-Survey) **Subgroup - HS Only**	I am confident in my knowledge of the engineering design cycle. (Post-Survey) **Subgroup - HS & Teachers**
Mean	2.00	2.17
Variance	0.67	0.17
Observations	10	6
Hypothesized Mean Difference	0.00	
Df	14.00	
t Stat	-0.54	
P(T<=t) two-tail	0.60	
t Critical two-tail	2.14	

Table 23: Results for a two sample mean t-test analysis of high school student self-confidence in their knowledge of the engineering design cycle. The results shown are for laboratories that included high school students only, which are compared to laboratories that included high school students, undergraduates and K-12 teachers.

	I am confident in my knowledge of the engineering design cycle. (Post-Survey) **Subgroup - HS Only**	I am confident in my knowledge of the engineering design cycle. (Post-Survey) **Subgroup - HS, UG, Teachers**
Mean	2.00	1.67
Variance	0.67	0.27
Observations	10	6
Hypothesized Mean Difference	0.00	
Df	14.00	
t Stat	1.00	
P(T<=t) two-tail	0.33	
t Critical two-tail	2.14	

Table 24: Results for a two sample mean t-test analysis of high school student self-confidence in their ability to conduct engineering research. The results shown are for laboratories that included high school students only are compared to laboratories that included high school students, undergraduates and K-12 teachers.

	I am confident in my ability to conduct engineering research. (Post-Survey) **Subgroup - HS Only**	I am confident in my ability to conduct engineering research. (Post-Survey) **Subgroup - HS & UG**
Mean	2.80	1.29
Variance	0.40	0.24
Observations	10	7
Hypothesized Mean Difference	0	
df	15	
t Stat	5.57	
P(T<=t) two-tail	5.40E-05	
t Critical two-tail	2.13	

Table 25: Results for a two sample mean t-test analysis of high school student self-confidence in their ability to conduct engineering research. Laboratories that included high school students only are compared with laboratories that included high school students and teachers.

	I am confident in my ability to conduct engineering research. (Post-Survey) **Subgroup - HS Only**	I am confident in my ability to conduct engineering research. (Post-Survey) **Subgroup - HS & Teachers**
Mean	2.80	3.17
Variance	0.40	0.97
Observations	10	6
Hypothesized Mean Difference	0	
df	8	
t Stat	-0.82	
P(T<=t) two-tail	0.44	
t Critical two-tail	2.31	

Table 26: Results for a two sample mean t-test analysis of high school student self-confidence in their ability to conduct engineering research. Laboratories that included high school students only are compared with laboratories that included high school students, undergraduates and teachers.

	I am confident in my ability to conduct engineering research. (Post-Survey) Subgroup - **HS Only**	I am confident in my ability to conduct engineering research. (Post-Survey) Subgroup - **HS, UG, Teachers**
Mean	2.80	2.00
Variance	0.40	0.40
Observations	10	6
Hypothesized Mean Difference	0	
df	11	

t Stat	2.45	
P(T<=t) two-tail	0.03	
t Critical two-tail	2.20	

Table 27: Results for a two sample mean t-test analysis of high school student self-confidence in their knowledge of engineering disciplines. Laboratories that included high school students only are compared with laboratories that included high school students and undergraduates.

	I am confident in knowledge of the engineering disciplines. (Post-Survey) Subgroup - **HS Only**	I am confident in my knowledge of the engineering disciplines. (Post-Survey) Subgroup - **HS & UG**
Mean	2.10	1.86
Variance	0.54	0.14
Observations	10	7
Hypothesized Mean Difference	0	
df	14	
t Stat	0.89	
P(T<=t) two-tail	0.39	
t Critical two-tail	2.14	

Table 28: Results for a two sample mean t-test analysis of high school student self-confidence in their knowledge of engineering disciplines. Laboratories that included high school students only are compared with laboratories that included high school students and teachers.

	I am confident in knowledge of the engineering disciplines. (Post-Survey) **Subgroup - HS Only**	I am confident in my knowledge of the engineering disciplines. (Post-Survey) **Subgroup - HS & Teachers**
Mean	2.10	2.17
Variance	0.54	0.97
Observations	10	6
Hypothesized Mean Difference	0	
df	8	
t Stat	-0.14	
P(T<=t) two-tail	0.89	
t Critical two-tail	2.31	

Table 29: Results for a two sample mean t-test analysis of high school student self-confidence in their knowledge of engineering disciplines. Laboratories that included high school students only are compared with laboratories that included high school students, undergraduates and teachers.

	I am confident in knowledge of the engineering disciplines. (Post-Survey) **Subgroup - HS Only**	I am confident in my knowledge of the engineering disciplines. (Post-Survey) **Subgroup - HS, UG, Teachers**
Mean	2.10	1.83
Variance	0.54	0.17

Observations	10	6
Hypothesized Mean Difference	0	
df	14	
t Stat	0.93	
P(T<=t) two-tail	0.37	
t Critical two-tail	2.14	

V. Conclusions and Future Work

Pre- and post-surveys of the pilot indicated that the undergraduate students and high school students in labs with both HS and UG students expressed higher levels of confidence in their ability to conduct research. High school students expressed higher confidence levels in the engineering design cycle and engineering discipline in the multi-layered mentorship program. Undergraduate students who were in labs where they peer-mentored teachers expressed higher levels of confidence in their skills as researchers than undergraduate students who did not peer-mentor in-service teachers. Future work includes revising interview questions with the aims of understanding why high students perceived themselves to be more knowledgeable about the engineering disciplines than their responses to interview questions indicated and to understand why teachers indicated lower confidence in their knowledge of the engineering design cycle. In order to understand the former question, more participant sampling is needed and also more insight into the background of the participants is needed.

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Appendix

Selected pre- and post-survey statements are provided.

1. I am confident in my ability to conduct engineering research.
2. I am confident in my knowledge of the engineering design cycle.
3. I am confident in my understanding the differences between the scientific method and engineering design method.
4. I am confident in my knowledge of the engineering disciplines.
5. I am confident in my mathematical abilities.

Selected interview questions are provided.

1. Were you aware of all of the engineering disciplines discussed in this program? Which ones were you unaware of prior to this summer? How did you learn about them?
2. Did you find your laboratory experiences at the college different or the same as laboratory experiments that you perform in your classroom laboratory experiments? Explain.
3. Do you teach the engineering design cycle? How do you teach it?
4. Do you think the engineering design process is the same as the scientific method? Explain.
5. Did having or not having undergraduate students/high school students/teachers in your lab change how you viewed engineering?
6. Did you work with undergraduate students/high school students/teachers or preparing presentations and posters? Was this process helpful? Explain.

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