K-12 Summer Engineering Outreach Programs – Curriculum Comparisons Between Ages, Minorities, and Genders.

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Abstract

Ensuring that the level of the material presented/used for a K-12 program is not too easy or too advanced can be a challenge to the instructor. Also ensuring that the material will be of interest to a variety of students (i.e., minorities, females, etc.) can be a challenge. Lawrence Technological University has two outreach programs each summer. One program, called the Summer Science Institute, is for high school juniors and seniors. The other program, called Summer Odyssey, is for middle school students. Both programs explain what engineers are, explain what engineers do, and promote problem solving skills. The students also experience various disciplines (or sub-disciplines) of engineering through a combination of presentations, laboratory experiences, and design work. In other words, much of the same material and activities are used for both programs. Although neither of these programs are specifically for minorities or women, a large portion of the students are female and approximately half are minorities. A review of the material/activities for the summer of 2004 is presented. In addition, in the summer of 2004, the students were surveyed to determine if the material was at the appropriate level, which activities were most valuable/useful, if certain activities appealed more for women, and if certain activities appealed more to minorities. These survey results and more are presented.

1. Introduction

While it is well known that K-12 outreach programs are necessary to promote engineering¹, it is difficult to know if the program being offered is too advanced or too simple for the student participants. Should high school students get more advanced projects and activities than middle school students? Is it acceptable to use the same activities for both groups?

It is also well known that more effective outreach needs to be focused on underrepresented groups for engineering, specifically females and minorities^{1,2,3,4}. Many K-12 outreach programs are not gender-specific (including male and female participants) nor race-specific

(including many races of students). Therefore, the activities must be worthwhile and attractive to all groups at once. Is this possible? Should the same activities be used for all genders and races?

Lawrence Technological University (LTU) has two outreach programs each summer. One program, called the Summer Science Institute (SSI), is for high school juniors and seniors. The other program, called Summer Odyssey, is for middle school students. Both programs are on-campus, explain what engineers are, explain what engineers do, and promote problem solving skills. The students also experience various disciplines (or sub-disciplines) of engineering through a combination of presentations, laboratory experiences, field trips, and design work.

While neither of these programs are race-specific (nor gender-specific), LTU's location in the Detroit Metro Area provides an opportunity to offer extensive outreach to African-American middle school and high school students who may not otherwise have exposure to engineering experiences. Besides the SSI and Summer Odyssey, LTU has other outreach programs to this population. For example, thanks in part to funding from the Engineering Information Foundation in New York, LTU was able to bring minority girls from Detroit's public housing communities to campus for two weeks during the summers of 2001 and 2002 to learn about engineering and technology. In addition, in 2001 Lawrence Tech became the only university in the Detroit area to serve as lead agency in delivering after-school programs at a Detroit school (Cerven Middle School)⁵.

2. Background

Programs that introduce engineering without utilizing advanced math and science are excellent tools for recruiting students to the engineering discipline. At the same time, these programs can give a good impression of what an engineer truly is.

The art of engineering involves skills such as design, estimation, analysis, synthesis, and visualization. The best way to learn the art of engineering is by doing engineering. This can be accomplished by using plenty of hands-on activities. In fact, the most successful outreach programs use mainly a hands-on approach^{1, 6, 7}. Moreover, these programs have successfully recruited and retained women and minorities, as well as improved their attitude toward math and science^{e.g., 6, 7, 8}.

A very effective type of hands-on project has been labeled as a "Design, Build, and Test (DBT) Project." DBT projects have been effectively used as an engineering and science tool for more than 15 years. The original idea arose from simple reasoning about teaching. If one wanted to teach someone how to ski, then lecturing about the principles of skiing is not enough. The student should actually ski. Similarly, to teach a student how to do engineering requires more than lecturing about the principles of engineering – the student should actually engage in engineering. There are many publications presenting the accolades of DBT projects at both college and high school levels^{e.g., 9, 10, 11}. DBT projects are excellent tools to teach engineering students who have spent time gaining a technical background and foundation, however DBT

projects can be a more effective tool for students who have little or no technical training, but may have an interest in pursuing an engineering education. The key elements in any DBT project are: 1) problem definition, 2) modeling, 3) design method, 4) prototyping, 5) project management.

Some of the activities used in the SSI and Summer Odyssey are DBT projects. The DBT projects used in the SSI and Summer Odyssey are set-up as competitions between student groups. Because of the competitive nature of real-world engineering, this competition format is a worthwhile component to the students. By the end of the competitions, the students have recognized: 1) what engineering is, 2) that science/engineering can be exciting, 3) how to work on a team, 4) pride of workmanship¹², 5) what an open-ended project is and how to solve the problem¹³, 6) that many assumptions must be made during the course of a project and those assumptions are usually proven to be valid^{14, 15}, and 7) that they have the ability to be engineers. It is hoped that the summer programs will lead many new students towards development of a personal design approach.

3. LTU Summer Programs

A. Summer Science Institute

The Summer Science Institute at Lawrence Technological University has been operating for over 37 years. The program is recognized as one of the Midwest's oldest and most respected engineering and science programs for exceptional high school students. The SSI is limited to outstanding students who have demonstrated superior academic achievement. The students must be in high school, and many have completed two years of math and one year of chemistry. The students must have a "B" average with nothing lower than a "B" in high school math and science courses.

The program spans over 5 weeks with a different discipline each week. Some of the week sessions include engineering, chemistry, physics, computer science, and math. In the past, each student participated in all 5 sessions. Last year the format was changed so that a student could participate in only one session if desired or more. Each day contains 6 hours of activities (i.e., learning material) with a one hour break for lunch. The students get a taste of college life as they interact closely with faculty and current students. The author of this paper was the instructor for the 2004 SSI Engineering Week. He also employed the assistance of a current mechanical engineering undergraduate student. This is a good aspect to incorporate into a K-12 program, because the young students will get to know an actual undergraduate student doing real engineering that they can aspire to someday.

B. Summer Odyssey

Summer Odyssey is a middle school age program (ages 11-15). Two different week-long sessions are available. One is called the Wizards and the other is called the Explorers. Each of these sessions is run twice so that all the sessions are operated over a 4 week period. Each day is

6 hours long with 4 topics each day and a half hour break for lunch. The Wizards topics are computer-aided design, basic wood model design (architecture), lego robots, and graphic animation. The Explorers topics are engineering, computer diagnosis, lego robotics, and web design. The author of this paper instructed the 2004 Explorers engineering sessions.

4. 2004 Engineering Programs

A. Summer Science Institute

Since the SSI is a week-long program consisting of 6 hour days, it is possible to use a combination of presentations, laboratory experiences, hands-on (DBT) activities, field trips, and design work. The week begins with an overview (PowerPoint presentation) of the various engineering fields. Next the instructor has an interactive discussion with the students to define what an engineer is and what an engineer does. Especially important is discussing how an engineer is different than a scientist. This leads into an interactive discussion about problem solving, design, and the design process. This is an important part of the day so that the students will be prepared to do some original design work and hands-on activities throughout the week. To get the students' minds "fired-up" and to promote creativity (i.e., thinking outside the box), a problem solving session is begun. The students are put into teams of approximately 4 students, and are given "riddles." The teams can only ask the instructor yes or no questions.

The students then begin their first design experience/hands-on activity. The design activities are completed by teams of 2 or more students. The teams compete with one another to accomplish the best design. This keeps the motivation high and promotes teamwork. The first design is an egg drop competition. Each team is given 25 pieces of paper, one piece of flimsy cardboard (such as a file folder), cellophane tape, scissors, one raw egg, and one cooked egg (see Figure 1). The cooked egg can be used for testing. If the students crack the cooked egg, they do not get another one. The uncooked egg, and its package are to be dropped from a height of 10 feet to a hard floor. If successful the egg and package will be dropped from 20 feet to a hard floor (see Figure 2). The egg must be able to be inserted into the package in 60 seconds by the instructor without verbal assistance and removed by him within 60 seconds (the package is allowed to be partially destroyed for removal). Therefore, written instructions must be included with the egg package. The teams have 2 hours to complete the design, notes, construction, and any tests of their packages. The team is judged/scored on their pre-build sketches and schematics, their written instructions, the time to insert and remove the egg from the package, and the success of the drop test. At the conclusion of the testing, a presentation is given by the instructor about packaging and impact testing to show the real-world application.

Figure 1: Designing and building the egg package.

Figure 2: One of the drop tests (left photo). The shown design used a paper-and-tape parachute successfully. An unsuccessful package and the resulting egg splatter (right).

The next activity involves measurements and measuring. The students are divided into two groups. Each group is given an aluminum pie pan, a mirror, and a 12 inch ruler. Each group must measure the height of building, tree, or other tall object (e.g., flagpole) using only the given equipment. Also each group must measure the width of a geographical feature. For example a parking lot can be used, to simulate a canyon or a raging river. Therefore, the students cannot cross over the terrain to measure its width. The measurement must be accomplished from the edge. This is both a problem solving exercise and a great tool for teaching the art of estimation and measurement units.

Next the students build a solar oven from a cardboard box, some reflective material (e.g., aluminum foil or shiny poster board), aluminum baking pans, flat black spray paint, an oven cooking bag (like the ones used to cook a turkey), and spray adhesive (see Figure 3). The students learn about heat transfer (all three modes: conduction, convection, and radiation) as well as alternative energy. The students are quite amazed that a cardboard solar oven can reach up to 400°F in less than 4 minutes. The students actually bake biscuits in the ovens and eat them. Some student designs are shown in Figure 4.

Figure 3: Building a cardboard solar oven

Figure 4: Three student designed, built, and tested solar ovens

The students take a tour of the LTU Vehicle Dynamics Laboratory which houses the world's only 4-wheel drive chassis dynamometer. Faculty are available to operate the dynamometer with a 4-wheel drive vehicle in place.

The students run a table-top-sized working model of a fossil-fueled steam power plant. Called the "Rankine Cycler™", produced by Turbine Technologies Ltd. of Chetek, Wisconsin, the actually looks and behaves similar to a real steam turbine power plant and actually generates electricity using only propane and water. The students get to use a modern computer data acquisition system, and can use the data to determine how much power was produced and how efficiently the plant performed.

One day is used for a field-trip to the BASF plant and laboratories. The students get to meet and watch engineers at work. The students tour an automotive parts plant, design, and testing facility. In addition, the students tour a laundry soap and dishwashing machine soap testing laboratory as well as a laboratory used to design and test new products. The laboratories allow the students to see real-world engineering applications, while the plant allows the students to experience manufacturing.

The week concludes with a bridge design, build, and test competition. The students assemble teams of 3. Each team is given 100 plastic drinking straws and one roll of translucent tape (see Figure 5). A minimum number of materials should be used. The bridge must span more than 20 inches and must be able to support a brick. If the bridge can support one brick, more bricks will be placed on the structure. The teams are judged/scored on their pre-build sketches and schematics, any written instructions or plans, the number of bricks supported, the amount of tape used, and the number of straws. At the conclusion of the testing, a presentation is given by the instructor about bridges to show the real-world application. Also the instructor demonstrates the extreme case of supporting 3 bricks with 4 straws (the bricks act as part of the bridge).

Figure 5: Building a drinking straw bridge.

B. Summer Odyssey

The Summer Odyssey Engineering session is only one and a half hours a day for 5 days, so there is not enough time for all of the activities from the SSI. In fact, time permitted only three of the activities: problem solving, the egg drop, and the bridge competition. The week began similarly with an overview (PowerPoint presentation) of the various engineering fields, the discussion defining what an engineer is and what an engineer does, and an interactive discussion about problem solving, design, and the design process. Next the problem solving session is begun. The same riddles (from SSI) were given and the teams could only ask the instructor yes or no questions. The egg drop competition was completed next, followed by the bridge competition. All rules and scoring remained the same as for the SSI. The presentations were given following each competition.

5. Survey and Results

An entrance survey was completed by the students at the beginning of the first day. An exit survey was completed at the end of the week. Much of the survey is quantifiable using a 5-point Likert scale, but written responses were also gathered. Questions asked on the survey with the rating scales are shown in the Appendix.

A. Summer Odyssey – Middle School Students

There were 48 students that participated (and completed surveys) in the 2004 Summer Odyssey. The average grade level was entering the 8th grade. Of all the students, 25% were females and 40% were minorities. 81% have a relative that is an engineer.

Summer Odyssey – All participants

As shown on Table 1, before the week's program, the students felt as though they knew what engineering was. On a scale of 1 to 5, where 1 is "strongly disagree" and 5 is "strongly agree," the average student response was 3.5, with a median of 4, and a standard deviation of 0.83. By the end of the week, they felt that they had a slightly better understanding of what engineering is with an average score of 3.5, a median of 4, and a standard deviation of 0.83. Of all the students, 54% gained a better perspective of engineering by week's end, 33% remained unchanged, and only 13% had less of a perspective.

Table 1 also shows that before the week's program, the students were split (or not sure) whether they wanted to study at college to be an engineer. On a scale of 1 to 5, where 1 indicates they strongly did not want to be an engineer and 5 indicates that they strongly did, the average student response was 3.3, with a median of 3, and a standard deviation of 1.1. At the end of the week, their opinion did not change considerably with an average score of 3.2, a median of 3, and a standard deviation of 1.2. This result is not surprising since one week is unlikely to change their interest. More time and reflection would be more likely to decide on a career in engineering.

	strongly disagree	disagree	no opinion	agree	strongly agree
Before program: I feel that I know what engineering is	0	13.6	29.5	47.7	9.1
This week gave me a better perspective of what engineering is	4.7	4.7	7	46.5	37.2
Before program: I am considering studying engineering in college	6.8	9.1	45.5	22.7	15.9
Now that the week is over, I am considering becoming an engineer	14.0	9.3	34.9	27.9	14.0

Table 1. Percentage of Summer Odyssey students agreeing with the statements concerning their understanding and consideration of engineering before and after the program

Each of the three activities were rated. The egg drop competition was their favorite, the bridge competition was next, and the problem solving was their least favorite. This result is no surprise as the middle school students tend to like hands-on activities better than purely mental exercises.

The students rated their overall week's experience on a scale of 1 to 5 with 1 being unsatisfactory and 5 being excellent (see Table 2). The students had a good experience with an average score of 4.1, a median of 4 and a standard deviation of 0.77. In addition, the students agreed that the week met their expectations with an average score of 3.7, a median of 4, and a standard deviation of 0.89 (see Table 2). Student comments ranged from, "I thought this class would be dumb, but it rocked," to, "I didn't really learn anything, and the class was kind of boring."

	unsatisfactory	poor	satisfactory	good	excellent
How would you rate your experience of the engineering portion of the week?	0	2.4	19.0	47.6	31.0
	strongly disagree	disagree	no opinion	agree	strongly agree
I got what I wanted out of the engineering sessions this week (the session met my expectations).	0	7.1	33.3	38.1	21.4

Table 2. Summer Odyssey student program satisfaction ratings (in percent)

Summer Odyssey – Females

Because only 25% of the students were females, the sample size is small. Nonetheless, distinct trends are still notable.

At the beginning of the week, both females and males average score was 3.5 when given the statement that they knew what engineering was (see Table 3). By the end of the week, the females felt that their perspective of what engineering is did not change scoring 3.2. On the other hand, the males scored 4.4 indicating that their perception was better by week's end.

At the beginning of the week when given the statement, "I am considering studying to be an engineer," the average female score was 2.7 as opposed to the male score of 3.5 (see Table 3). This may be due to the younger average grade level of the females; females were entering the 7th grade on average, while males were entering 8th grade. By the end of the week the female score went down to 2.3 while the male score remained 3.5.

	strongly disagree		disagree		no opinion		agree		strongly agree	
	F	M	F	M	F	M	F	M	F	M
Before program: I feel that I know what engineering is	0	0	9.1	15.2	36.4	27.3	54.5	45.5	0	12.1
This week gave me a better perspective of what engineering is	18.2	0	18.2	0	9.1	6.3	36.4	50.0	18.2	43.8
Before program: I am considering studying engineering in college	18.2	3.0	18.2	6.1	45.5	45.5	9.1	27.3	9.1	18.2
Now that the week is over, I am considering becoming an engineer	36.4	6.3	18.2	6.3	36.4	34.4	0	37.5	9.1	15.6

Table 3. Percentage of Summer Odyssey female and male students agreeing with the statements concerning their understanding and consideration of engineering before and after the program

The activities rated the same for females and males with the egg drop competition being the favorite, and the problem solving being the least favorite.

Although both females and males had a favorable experience (see Table 4), the males scored higher with a 4.3 while the females scored 3.4. This may be due to the competitive nature of some activities. In addition, both males and females agreed that the week met their expectations (see Table 4), but the males scored slightly higher at 3.8 as opposed to the females at 3.5.

	unsatisfactory		poor		satisfactory		good		excellent	
	F	M	F	M	F	M	F	M	F	M
How would you rate your experience of the engineering portion of the week?	0	0	9.1	0	54.5	6.5	27.3	54.8	9.1	38.7
	strongly disagree		disagree		no opinion		agree		strongly agree	
	F	M	F	M	F	M	F	M	F	M
I got what I wanted out of the engineering sessions this week (the session met my expectations).	0	0	18.2	3.2	36.4	32.3	27.3	41.9	18.2	22.6

Table 4. Female and male student Summer Odyssey program satisfaction ratings (in percent)

Summer Odyssey – Minorities

At the beginning of the week, minority students scored 3.4 while white students' average score was 3.5 when given the statement that they knew what engineering was (see Table 5). By the end of the week, the minority students felt that their perspective of what engineering is did not change much scoring 3.7. On the other hand, the white students scored 4.2 indicating that their perception was better by week's end.

At the beginning of the week when given the statement, "I am considering studying to be an engineer," the average minority student score was 3.1 as opposed to the white student score of 3.5. By the end of the week the minority student score went down to 2.7 while the white student score remained fairly steady at 3.4.

	strongly disagree		disagree		no opinion		agree		strongly agree	
	M	W	M	W	M	W	M	W	M	W
Before program: I feel that I know what engineering is	0	0	18.8	9.5	25.0	38.1	50.0	38.1	6.3	14.3
This week gave me a better perspective of what engineering is	6.7	5.0	13.3	0	6.7	10.0	46.7	45.0	26.7	40.0
Before program: I am considering studying engineering in college	12.5	4.8	12.5	4.8	43.8	38.1	18.8	28.6	12.5	23.8
Now that the week is over, I am considering becoming an engineer	26.7	10.0	26.7	0	13.3	45.5	13.3	30.0	20.0	15.0

Table 5. Percentage of Summer Odyssey minority and white students agreeing with the statements concerning their understanding and consideration of engineering before and after the program

The activities rated the same for minority students and white students with the egg drop competition being the favorite, and the problem solving being the least favorite.

Although both minority students and white students had a favorable experience (see Table 6), the white students scored slightly higher with a 4.1 while the minority students scored 3.9. When considering the female score in the previous section, the slightly lower minority score here may be due to a larger percentage of minority females than white females. Both minority students and white students agreed that the week met their expectations (see Table 6), but the white students scored slightly higher at 3.75 as opposed to the minority students at 3.71.

	unsatisfactory		poor		satisfactory		good		excellent	
	M	W	M	W	M	W	M	W	M	W
How would you rate your experience of the engineering portion of the week?	0	0	7.1	0	28.6	15.0	35.7	65.0	28.6	20.0
	strongly disagree		disagree		no opinion		agree		strongly agree	
	M	W	M	W	M	W	M	W	M	W
I got what I wanted out of the engineering sessions this week (the session met my expectations).	0	0	7.1	5.0	28.6	40.0	50.0	30.0	14.3	25.0

Table 6. Minority and white student Summer Odyssey program satisfaction ratings (in percent)

Summer Odyssey – Level of Material

On a scale of 1 to 5 with 1 being “too easy” and 5 being “too advanced”, all student groups’ (male, female, minority, and white) average response to the level of material was that the material was “just right” (i.e., 3). Table 7 shows the results from all Summer Odyssey participants.

	too advanced	advanced	just right	easy	too easy
The level of material that we covered during the engineering portion of the week was:	2.4	4.9	68.3	19.5	4.9

Table 7. Summer Odyssey student ratings (in percent) for the level of material covered during the engineering program

B. Summer Science Institute – High School Students

There were 12 students that participated (and completed surveys) in the 2004 Summer Science Institute. The average grade level was entering the 11th grade. Of all the students, 50% were females and 83% were minority. 67% have a relative that is an engineer.

Summer Science Institute – All participants

As shown on Table 8, before the week's program, the students felt as though they knew what engineering was. On a scale of 1 to 5, where 1 is "strongly disagree" and 5 is "strongly agree," the average student response was 3.25, with a median of 3, and a standard deviation of 1.1. By the end of the week, they felt that they had a much better understanding of what engineering is with an average score of 4.0, a median of 4, and a standard deviation of 0.86. Of all the students 83% gained a better perspective of engineering by week's end, 8% (1 student) remained unchanged, and only 8% (1 student) had less of a perspective.

As shown in Table 8, before the week's program, the students were split whether they wanted to study at college to be an engineer. On a scale of 1 to 5, where 1 indicates they strongly did not want to be an engineer and 5 indicates that they strongly did, the average student response was 3.4, with a median of 4, and a standard deviation of 1.7. Table 8 indicates that 41.7% of the students are strongly considering engineering, but that contrasted with 25% that strongly did not. (Why, then, were these students spending a week of their summer learning about engineering? The students responded that either their parents made them attend or that they were just looking for something constructive to do.) At the end of the week, their average opinion went down with an average score of 2.7, a median of 3, and a standard deviation of 1.4. The largest change is indicated in the "strongly agree" column, dropping from 41.7% to 8.3%. These results are somewhat surprising for at least two reasons. First, these results are not due to the material being too advanced considering that the students thought that the level of material was "just right" (score of approximately 3). In addition, the students rated their overall experience as good (4 on a scale of 1 to 5), and the week met their expectations (4 on a scale of 1 to 5).

	strongly disagree	disagree	no opinion	agree	strongly agree
Before program: I feel that I know what engineering is	0	25.0	41.7	16.7	16.7
This week gave me a better perspective of what engineering is	0	0	33.3	33.3	33.3
Before program: I am considering studying engineering in college	25	8.3	8.3	16.7	41.7
Now that the week is over, I am considering becoming an engineer	33.3	8.3	25.0	25.0	8.3

Table 8. Percentage of SSI students agreeing with the statements concerning their understanding and consideration of engineering before and after the program

Each of the eight activities were rated. In order of favorite to least favorite, the results are as follows: egg drop, problem solving, solar oven, bridge competition, measurements, vehicle dynamics lab tour, power plant experiment, BASF tour. Note that for these high school students, the problem solving was enjoyed more than the bridge competition. This is the opposite result of the middle school students. This result is expected as the high school students are more mature

in their mental skills. In addition, the high school students were in the SSI program because of their high academic achievement.

The students rated their overall week's experience on a scale of 1 to 5 with 1 being unsatisfactory and 5 being excellent (see Table 9). The students had a good experience with an average score of 4.0, a median of 4 and a standard deviation of 0.69. In addition, the students agreed that the week met their expectations with an average score of 4.0, a median of 4, and a standard deviation of 0.63. Student comments ranged from, "More fun than expected," to, "I'm not too interested in engineering. I needed to preoccupy my time and this class did that.... I may have been more interested if it was something corresponding to my career goals."

	unsatisfactory	poor	satisfactory	good	excellent
How would you rate your experience of the engineering portion of the week?	0	0	16.7	58.3	25.0
	strongly disagree	disagree	no opinion	agree	strongly agree
I got what I wanted out of the engineering sessions this week (the session met my expectations).	0	0	18.2	63.6	18.2

Table 9. SSI student program satisfaction ratings (in percent)

Summer Science Institute – Females

At the beginning of the week, females and males average scores were 3.3 and 3.2, respectively, when given the statement that they knew what engineering was (see also Table 10). By the end of the week, the females felt that their perspective of what engineering is increased scoring 3.9. Males saw a similar increase to a score of 4.0.

At the beginning of the week when given the statement, "I am considering studying to be an engineer," the average female score was 3.7 as opposed to the male score of 3.2. In fact, Table 10 shows that two-thirds of the females "strongly agreed" that they were considering studying to be an engineer. The remaining one-third "strongly disagreed" with none in the middle range. By the end of the week, the female score went down to 2.8, and likewise, the male score dropped to 2.5.

	strongly disagree		disagree		no opinion		agree		strongly agree	
	F	M	F	M	F	M	F	M	F	M
Before program: I feel that I know what engineering is	0	0	33.3	16.7	33.3	50.0	0	33.3	33.3	0
This week gave me a better perspective of what engineering is	0	0	0	0	33.3	33.3	33.3	33.3	33.3	33.3
Before program: I am considering studying engineering in college	33.3	16.7	0	16.7	0	16.7	0	33.3	66.7	16.7
Now that the week is over, I am considering becoming an engineer	33.3	33.3	0	16.7	33.3	16.7	16.7	33.3	16.7	0

Table 10. Percentage of SSI female and male students agreeing with the statements concerning their understanding and consideration of engineering before and after the program

The activities were rated slightly differently for females than for males. For the females, in order of favorite to least favorite, the results are as follows: egg drop, problem solving, solar oven, measurements, bridge competition, vehicle dynamics lab tour, power plant experiment, BASF tour. For the males, in order of favorite to least favorite, the results are as follows: egg drop, problem solving, solar oven, bridge competition, BASF tour, power plant experiment, measurements, vehicle dynamics lab tour. Most notably, for both males and females, problem solving ranked ahead of the bridge competition, as opposed to the Summer Odyssey students. Also measurements ranked much higher for females than for males, while bridge competition ranked lower for females than for males. This may be due to the fact that measurements was not a competition and the bridge activity was.

Although both males and females had a favorable experience as shown on Table 11, the females scored slightly higher with a 4.1 while the males scored 4.0. In addition, both males and females agreed that the week met their expectations, but the males scored slightly higher at 4.2 as opposed to the females at 3.8.

	unsatisfactory		poor		satisfactory		good		excellent	
	F	M	F	M	F	M	F	M	F	M
How would you rate your experience of the engineering portion of the week?	0	0	0	0	0	33.3	83.3	33.3	16.7	33.3
	strongly disagree		disagree		no opinion		agree		strongly agree	
	F	M	F	M	F	M	F	M	F	M
I got what I wanted out of the engineering sessions this week (the session met my expectations).	0	0	0	0	40.0	0	40.0	83.3	20.0	16.7

Table 11. Female and male student SSI program satisfaction ratings (in percent)

Summer Science Institute – Minorities

A comparison of minority student responses to white student responses is difficult since only 2 of the students are white. Nonetheless, a comparison is given below since the minority student responses are noteworthy.

At the beginning of the week, minority students scored 3.2 while white students average score was 3.5 when given the statement that they knew what engineering was (see Table 12). By the end of the week, the minority students felt that they had a good perspective of what engineering is scoring 4.2. The white students scored 3.0.

	strongly disagree		disagree		no opinion		agree		strongly agree	
	M	W	M	W	M	W	M	W	M	W
Before program: I feel that I know what engineering is	0	0	30.0	0	40.0	50.0	10.0	50.0	20.0	0
This week gave me a better perspective of what engineering is	0	0	0	0	20.0	100	30.0	0	40.0	0
Before program: I am considering studying engineering in college	30.0	0	0	50.0	10.0	0	10.0	50.0	50.0	0
Now that the week is over, I am considering becoming an engineer	30.0	50.0	10.0	0	30.0	0	20.0	50.0	10.0	0

Table 12. Percentage of SSI minority and white students agreeing with the statements concerning their understanding and consideration of engineering before and after the program

At the beginning of the week when given the statement, “I am considering studying to be an engineer” (see also Table 12), the average minority student score was 3.5 as opposed to the white student score of 3.0. By the end of the week the minority student score went down to 2.7 while the white student score remained dropped to 2.5.

For minority students, the activities were rated in order of favorite to least favorite as follows: egg drop, problem solving, solar oven, bridge competition, measurements and vehicle dynamics lab tour (equal), power plant experiment, and BASF tour.

Although both minority students and white students had a favorable experience (see Table 13), the minority students scored higher with a 4.2 while the white students scored 3.5. In addition, both minority students and white students agreed that the week met their expectations, scoring 4.0.

	unsatisfactory		poor		satisfactory		good		excellent	
	M	W	M	W	M	W	M	W	M	W
How would you rate your experience of the engineering portion of the week?	0	0	0	0	10.0	50.0	60.0	50.0	30.0	0
	strongly disagree		disagree		no opinion		agree		strongly agree	
	M	W	M	W	M	W	M	W	M	W
I got what I wanted out of the engineering sessions this week (the session met my expectations).	0	0	0	0	22.2	0	55.6	100	22.2	0

Table 13. Minority and white student SSI program satisfaction ratings (in percent)

Summer Science Institute – Level of Material

When given the statement, “The level of material was:”, on a scale of 1 to 5 with 1 being “too easy” and 5 being “too advanced”, the average student response was 3.2, the male student response was 3.3, the female student response was 3.1, the minority response was 3.2, and the white student response was 3.5. In general, this indicates that the level of material was “just right,” if not just a bit easy. Table 14 shows the results from all participants.

	too advanced	advanced	just right	easy	too easy
The level of material that we covered during the engineering portion of the week was:	0	16.7	41.7	41.7	0

Table 14. SSI student ratings (in percent) for the level of material covered during the engineering program

C. Level of Material Comparison Between Programs/Age Groups

Recall, that the Summer Odyssey students (middle school) rated the material “just right”; essentially this is the same rating as the SSI students (high school). Actually, the SSI students considered the material slightly more simple than the Summer Odyssey students (3.2 to 3.0). On the other hand, comparing Table 7 and Table 14, a higher percentage of SSI students (high school) than Summer Odyssey students (middle school) found the material advanced. (Recall that while three of the activities were identical between programs, the SSI students had additional activities.) The surprising fact here is that both the middle school students (Summer Odyssey) and the “honors” high school students found the material to be at the appropriate level (approximately) even though the material was essentially the same. Because most middle school and high school students are not exposed to much, if any, engineering in their school curriculum, the same material is worthy for both groups. The material only needs to be slightly advanced for the high school students. For example, the constraints (e.g., building materials or time limit) on the DBT projects can be tougher, or perhaps some more advanced modeling techniques can be used during the designing process. The instructor (i.e., the author of this paper) also noticed that there was no noticeable difference in the quality of the students’ designs from the middle school students to the high school students. Although a student’s maturity and thinking skills have progressed from middle school to high school, the student has not spent much time designing and problem solving.

6. Conclusion

Both programs were successful in meeting the expectations of the students and giving them a favorable experience. All students gained an understanding of what engineering is.

There was very little difference in scores and ratings between females and males. The main difference is that the females tend to have an aversion to multiple competitions. With the program format outlined here, there is not enough difference in their ratings to necessarily warrant radically different programs for males and females.

There was also very little difference between minority students' and white students' ratings. Therefore it is possible to operate a successful outreach program for multiple ethnic backgrounds.

Finally, it is possible to use the same activities for middle school and high school programs with slightly different conditions used for the high school activities. The interest in the various activities is slightly different with high school students enjoying problem solving more than middle school students, but the hands-on activities were well liked by both age groups.

Acknowledgements

The author thanks Dr. Robert Fletcher of the Lawrence Technological University Mechanical Engineering Department for his time, resources, and thoughtfulness during the development/implementation of the SSI and Summer Odyssey Programs; Dr. William Madden, chair of the LTU Natural Sciences Department and director of the SSI, Michele Vanootighem Bialo, LTU Operations and Marketing Manager for the Division of Continuing Education and Professional Development; Angelina Card, LTU Operations and Marketing Coordinator for the Division of Continuing Education and Professional Development; and Brandon Given, LTU ME student and assistant for the 2004 SSI Engineering Week.

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Appendix

Sample Introduction Survey

Gender: Male ☐ Female ☐

In what town/city do you live:

What year will you begin this fall in high school:

I feel that I know what engineering is.

Strongly disagree	disagree	no opinion	agree	strongly agree
1	2	3	4	5

Are your parents, relatives, or anyone that you know well an engineer: Yes No

I am considering studying engineering in college.

Strongly disagree	disagree	not sure	agree	strongly agree
1	2	3	4	5

What field?

What classes have you taken that will prepare you for engineering:

Math:

Science:

What colleges are you considering?

What are your favorite school activities (sports, clubs, etc.)?

What are your hobbies/interests?

What would you like to get out of this week?

Sample Exit Survey

This week gave me a better perspective of what engineering is:

None		about the same		strongly
1	2	3	4	5

Now that the week is over, I am considering an engineering major in college:

None		about the same		strongly
1	2	3	4	5

What field (if applicable)?

Rate your favorite activities this week. Put a 1 next to your favorite, a 2 next to your second favorite, etc. Label each activity.

- _____ problem solving
- _____ egg drop
- _____ measurements
- _____ solar oven
- _____ vehicle laboratory
- _____ small steam power plant
- _____ BASF tour
- _____ bridge building and competition

(NOTE: the Summer Odyssey students only rated the 3 activities that they did: problem solving, egg drop, and bridge competition.)

For your number 1 activity listed above, why was it your favorite?

For your least favorite activity listed above, why was it your least favorite?

I felt comfortable asking questions in class.

Strongly disagree	disagree	no opinion	agree	strongly agree
1	2	3	4	5

The instructor was willing and able to answer questions.

Strongly disagree	disagree	no opinion	agree	strongly agree
1	2	3	4	5

The instructor's presentations were well prepared.

Strongly disagree	disagree	no opinion	agree	strongly agree
1	2	3	4	5

How do you rate the instructor's ability to impart the course material?

Unsatisfactory	poor	satisfactory	good	excellent
1	2	3	4	5

How would you rate the instructor's overall performance?

Unsatisfactory	poor	satisfactory	good	excellent
1	2	3	4	5

How would you rate your experience of the week?

Unsatisfactory	poor	satisfactory	good	excellent
1	2	3	4	5

The level of material that we covered during the week was:

Too advanced		just right		Too easy
1	2	3	4	5

I got what I wanted out of this week (the week met my expectations).

Strongly disagree	disagree	no opinion	agree	strongly agree
1	2	3	4	5

Explain.

The students were also asked for "Additional comments/observations."