AC 2007-1669: ASSESSMENT OF GENDER DIFFERENCES ON RATINGS OF ENGINEERING LEARNING MODULES IN MIDDLE-SCHOOL YOUTH IN AN AFTER-SCHOOL SETTING

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Assessment of Gender Differences on Ratings of Engineering Learning Modules in Middle-School Youth in an After-school Setting

Abstract

For both genders characteristics of effective STEM (Science, Technology, Engineering, and Math) after-school programs include opportunities for youth to build competencies, form bonds with peers and staff, and participate in program decisions. After-school program characteristics found to foster STEM interest and persistence of girls in particular across age, race and ethnic diversity include collaborative, hands-on activities, mentoring, parent and community support, emphasis on practical applications, and teaching of science or engineering in a more holistic and social context [1,2,3,4,5,6,7]. In addition, programs for girls that combine hands-on activities, role models, mentoring, and career exploration have been shown to improve girls' self-confidence and interest in STEM courses and careers in particular. This paper presents statistical analyses of gender differences between youths' ratings of six engineering modules implemented in the *Techtronics* after-school program at Rogers Herr Middle School in Durham, North Carolina.

Introduction

Techtronics, an after- school engineering enrichment program for middle school students, has incorporated many of these characteristics as described above to maximize appeal for both genders while encouraging at-risk middle school students to pursue careers in engineering and science. An extension of the K-PhD Program at Duke University's Pratt School of Engineering, it is a partnership between the Pratt School of Engineering and Rogers-Herr Middle School in Durham, NC. Program goals include improving student competence and enthusiasm for science and engineering, and stimulating interest in pursuing careers in engineering and science with a special focus on minority and female students. Students are immersed in real-world engineering design challenges and asked to apply scientific principles they are learning as part of the N.C. Standard Course of Study to solve real-world problems. To sustain interest across genders, *Techtronics* links curriculum content to human applications, emphasizes helpfulness of technologies in solving problems for humanity, utilizes hands-on activities, provides both male and female role models through undergraduate and graduate Engineering Teaching Fellows, involves parents via Saturday demonstrations at the university, and encourages both boys and girls to ask questions and brainstorm designs in teams.

This paper presents statistical analyses of gender differences between ratings of six *Techtronics* engineering modules (Lego Robotics, Bridges, Heart Monitors (EKG), Solar Energy, Towers, and AM Radios) and provides in-depth assessment of these differences based on qualitative data and subsequent student interviews designed to identify factors contributing to the differential appeal and learning characteristics of these modules across gender. Based on these results, recommendations are made for future research studies as the *Techtronics* program expands over the next several years. In addition, insights into optimal ways to engage and inspire middle school students of both genders to engage in K-12 engineering education programs are offered.

Rationale for Study

STEM education experts cite as compelling evidence of school failure the repeated finding that girls are under-represented in science and engineering careers, yet "when career decisions are examined, many cite out-of-school or informal science experiences as playing a key role in their decision" [8]. Thus, it is particularly important to understand salient factors in designing and implementing successful out-of-school science and engineering enrichment programs that engage and appeal to both genders.

Studies of informal science and engineering education enrichment programs have recommended emphasizing human versus technological aspects of science in curriculum design to "increase the appeal of topics across gender" [9]. "Promoting science as a human inquiry, involving the hands and the heart as well as the brain, one's personal interests and tastes—rather than an anonymous application of a universal method" [1] has been found to increase the appeal of STEM fields to girls in particular. Further research on engaging girls in effective STEM after-school educational enrichment indicates that "the way STEM activities are taught and introduced" is critical[1]: for instance, the particular examples used to illustrate principles in physics can be crucial—using the heart to illustrate the principles of a pump was found to interest girls more than an oil rig; and the need "to put effort into making sure the way the material is presented reflects girls' interests in human service occupations, human needs, and biological systems" was stressed [1].

Researchers also agree that mentors and role models are important from the early grades and throughout a woman's career in science or engineering [4, 10, 11, 12]. Programs for girls combining hands-on activities, role models, mentoring, internships, and career exploration have improved girls' self-confidence and interest in STEM courses and careers [13,14].

For both genders, hands-on experiences such as using tools and equipment have been found to enhance interest in science [4] and are related to higher math and science achievement [2]. Girls, in particular, were six times more likely to consider engineering as a career following hands-on engineering activities [15].

Differences were found between the way girls and boys interact with computers [16]. Girls preferred interacting with people to working on computers, which they viewed as "tools" while boys showed more preference for working on computers, which they viewed as "toys" [16]. Girls were more often engaged by software that provided opportunities for collaboration, strategizing and critical thinking, and creative aspects of programming[16, 17].

Engagement in hands-on activities using science equipment was related to higher science and math achievement for both genders [2]. Since several studies noted that boys tended to dominate science-oriented activities involving special equipment [4, 18], this suggests the need for balanced numbers of boys and girls in group composition and awareness of the importance of encouraging and valuing questions and active participation of both genders during hands-on engineering design and building opportunities.

Furthermore, STEM content, per se, was not seen as "gender specific". Cultural relevance was identified as another important factor for effective engagement of both boys and girls in STEM activities, and connection with the community in particular for females. For both genders, characteristics of effective youth development programs included opportunities for youth to share in program decisions, develop and articulate their own goals, build competencies, and form bonds with peers and staff [1].

Based on findings from the preceding research, the following hypotheses were made regarding male/female ratings for specific *Techtronics* engineering modules (Lego Robotics, Bridges, Heart Monitor (EKG), Solar Energy, Towers, and AM Radio):

1. Since girls have been shown to prefer human versus technological aspects of science, and are engaged by projects illustrative of "human service occupations, human needs, and biological systems", it was predicted that female students would rate the EKG module more positively than males.
2. Since boys showed more preference for working on computers and girls were found to prefer interacting with people to working on computers, it was predicted that boys would rate the Lego Robotics module more positively than girls since this module involves a significant amount of computer programming.
3. Both genders would be engaged and give positive ratings to the hands-on building components and to the use of physical tools for all modules with no major differences between genders in this respect.

This paper presents statistical analyses of gender differences between ratings of these six *Techtronics* engineering modules (Lego Robotics, Bridges, Heart Monitor (EKG), Solar Energy, Towers, and AM Radio) along with follow up qualitative analyses of open-ended questions and subsequent individual student interviews to elucidate important dimensions of engineering enrichment activities for each gender.

***Techtronics* Program- Setting for Data Collection**

Techtronics provides an ideal setting to test gender preferences for an engineering enrichment curriculum. Operational since 2001, to date it has served 222 students, with strong minority representation (76% African American) and balanced gender representation (46% females). Formative and summative student surveys have resulted in improved curricular modules and suggest strong positive program related trends on student self-reported competence in science, student enthusiasm for engineering and science, and student interest in further studies in science and engineering.

Graduate and undergraduate engineering teaching fellows introduce students in grades 6-7 to four branches of engineering (electrical and computer, civil and environmental, mechanical, and biomedical) through hands-on projects. *Techtronics* utilizes two graduate and 10 undergraduate Engineering Teaching Fellows from the Pratt School of Engineering as mentors, with approximately equal numbers of male and female Fellows serving as mentors. Two classes of approximately 20 middle-school students each are segmented into groups of four students paired with a group leader. Sixth and seventh grade students are taught in two separate sections with approximately 20 students per section annually. The high ratio of Engineering Teaching Fellows to middle school students allows completion of complex projects that would not work as well in a class taught by only one instructor. Each module takes approximately 10 hours or five days to complete. *Techtronics* meets once weekly for two hours after school with each module spanning approximately five weeks. A brief description of each of the modules analyzed in the current paper is presented below. More complete descriptions of all 6 engineering modules as well as the programmatic structure have been previously provided [19, 20, 21]. Portions of the Towers, AM Radio and Solar Energy projects are published on the TeachEngineering Digital Library (www.teachengineering.org), part of the National Science Digital Library.

Lego Robotics

Taught in both *Techtronics* I and II, Lego Robotics introduces students to concepts in mechanical engineering, computer science, and electrical and computer engineering. The materials available for these modules are some of the best for allowing students to creatively design high technology projects. The Lego Mindstorms kits and the Robolab software make it possible for students to create and build their own robots (www.legomindstorms.com). Student groups are presented with the challenge of designing and constructing a vehicle out of Legos to navigate the "terrain" of Mars or some other maze. For the Mars project, the rovers are required to navigate an obstacle course built to simulate the surface of Mars and climb a ramp that represents the largest volcano in the solar system, Olympus Mons. Through initial frustration and eventual success, students meet challenges they did not think possible. This project provides opportunities for students to discover and discuss advantages and disadvantages of various designs. The significant portion of time spent on Robolab programming, though sometimes tedious, is ultimately rewarding when students see what their robots can accomplish. Students also spend a great deal of their time iterating designs to make their robots sufficiently robust so that they do not fall apart if dropped or ran into a wall. Consolidation of learning is achieved when students discuss which designs were most effective and why.

Heart Monitors

Techtronics I teaches 6th grade students that biomedical engineers utilize electrical activity in the heart muscle to measure heart rate using a circuit. In order to learn these concepts, students are introduced to the biology of the heart as well as basic concepts of electric circuitry such as filters, amplifiers, and Ohm's law. Learning circuits is exciting for youth because it explains the green boards they have probably seen in a number of electronic devices. Fellows discuss how circuit boards are constructed and how the tiny electronic components on them function. Since electrical circuitry is relatively complex, it is difficult to develop creative projects for students in which they can build something through trial and error experimentation. Students assemble a heart monitor circuit kit in groups of four and become excited when given the opportunity to measure their own heart rates. In this portion of the project, inquiry is encouraged as students measure their heart rates while doing different physical activities. These kits require soldering necessitating close supervision. Though highly structured,

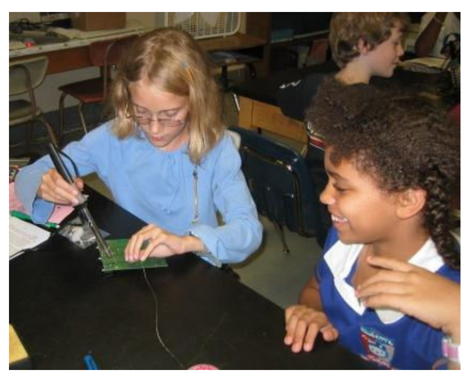

Figure 1 - Students soldering heart monitor kits.

students love this activity since the concept of melting metal fascinates them. Soldering and building their own circuit boards is especially captivating to students during this project.

Bridge Module

The bridge module introduces students to civil engineering through the design, construction and testing of balsa wood bridges both via computer modeling and in real life. During the first class of this module, students are introduced to concepts such as types of bridges, failure, forces, and strength-to-weight ratio. After initial exposure to these concepts, student teams, facilitated by an Engineering Teaching Fellow, are presented with the challenge of designing bridges with the goal of holding a specified amount of weight and meeting set design constraints such as minimum span and maximum height. First, student teams brainstorm their designs and draw them on butcher paper. The large size of this paper supports students' creativity at the outset since they are not constrained by having to work on more structured graph paper or by the structure of a computer. Next, students design and test their designs on Modelsmart 3D, a computer-aided design (CAD) and analysis software package that accurately simulates how bridges would react to a given applied load. In this first exposure to CAD, students design and test a two- dimensional side of their actual bridge rather than the entire structure. Engineering Teaching Fellows monitor team progress as well as facilitate and promote team brainstorming and co-operation. Students spend the majority of the unit, 2-3 days, designing and building their bridges with balsa wood. Completed bridges are finally tested, and students are asked to compare the actual tests to the CAD analysis.

Towers Module

The 7th grade *Techtronics* II Towers Module builds upon work previously done during the balsa wood bridges project in *Techtronics* I, and extends that module by helping students further develop their 3D visualization and design skills. "The main differences between building towers in Techtronics II and building balsa wood bridges in Techtronics I are designing and building in 3D and building a physically larger and more exciting structure. New design challenges surface from building a 3D structure. A bridge can easily be designed in two dimensions because students simply draw one side, build it twice, and connect both sides…. Designing in three dimensions provides new challenges."[20] Building a Tower also differs from a bridge because students must think about some of the three dimensional aspects before they begin the design process. This module extends the use of Modelsmart 3D to design and test structures before they are built. CAD is

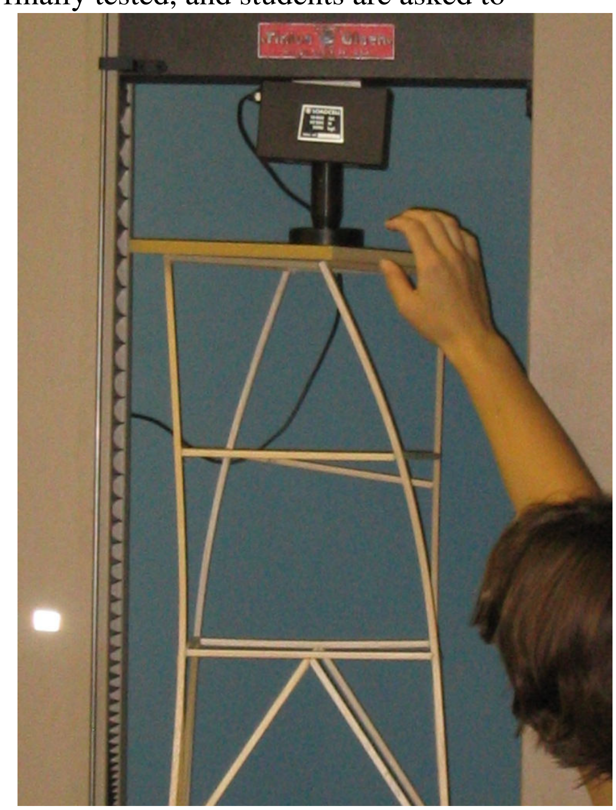

Figure 2 - A sample tower is tested in a compression machine to demonstrate the importance of diagonal bracing.

also a useful way for students to learn about the Cartesian coordinate system. The Towers Module utilizes thicker balsa wood sections than the Bridges Module (1/4" square rather than 1/8") to build taller and more robust structures. Despite these differences, the Towers module is more similar than different to the Bridge Module. An emphasis on real world applications of the module is provided by an analysis of real-world towers, via discussing the history of design and construction of the world's tallest buildings. Structural engineering provides the content basis for both modules. Both modules begin with a planning activity in Modelsmart 3D prior to actual construction, and finally, both modules involve similar tools and construction techniques in which groups build with balsa wood.

AM Radio Module

The AM Radio Module in *Techtronics* II revisits the electrical engineering and circuit design concepts introduced in Techtronics I during the Heart Monitor Module. Students are introduced to the history of AM radios through a web-based research activity that asks students to search specific websites for answers to questions on a worksheet. Students are then introduced to the relationship between electricity and magnetism through a series of demonstrations provided by the Duke Physics Department. They learn how a wire coil can be used to create an antenna. After learning about soldering, students have the opportunity to solder like electrical engineers to build their radios on circuit boards. Students become excited when sound finally emerges from their creations. Next, students dismantle a manufactured radio for comparison with their radio and are able to identify parts on the real radio that match parts on their radios. As with the Heart Monitor Module, soldering the kit together is the largest portion of this activity, taking approximately two days. Although tedious, students become excited over liquefying solder when assembling an electric circuit.

Solar Energy

The Solar Energy Module introduces the use of solar thermal energy and photovoltaic panels through the design and construction of solar ovens and solar cars. Students also gain an appreciation for the importance of renewable energy and recycling. In building solar ovens, teams of students are guided through an inquiry-based learning process to foster understanding of insulation, emissivity, and heat transfer. The students are given several materials and allowed to build their own unique designs. Although fellows guide them to ensure that their solar ovens will work, students have more freedom to make decisions on this project than most projects like the AM Radio since it is less technology based than other modules. During the second half of this module, solar car kits are built to teach application of solar photovoltaic panels. Each of these projects takes about two class periods. This module concludes with the testing the solar ovens using multimeters and thermocouples as well as baking some cookies. Students are always enthusiastic about racing their cars as well and somewhat surprised at how fast their solar cars can move.

Data Collection, Analysis and Results

Data collected for analysis consisted of *Techtronics* End-of-Module Student Surveys collected between September 2003 and December 2006. Surveys were administered during the last class of a particular module or the first class of the next module. Since all students were not present for every class, not all students are represented in the results for a given module. On these surveys, students rate *Techtronics* Modules quantitatively on enjoyment, learning, instructors' performance, and difficulty. Quantitative questions from the End-of-Module Survey follow:

Please tell us how you feel about each of the following statements by circling one number on each 5-point scale.
Choose one answer for each statement.

	Strongly disagree	**Disagree**	**Uncertain**	**Agree**	**Strongly agree**
1. I enjoyed this module.	1	2	3	4	5
2. I learned from this module.	1	2	3	4	5
3. The instructors as a whole did a good job teaching this module.	1	2	3	4	5

	Too Easy		**Just Right**		**Too Hard**
4. Rate the difficulty of this module.	1	2	3	4	5

On this same survey, students are also given the opportunity to answer three open-ended questions:

5. What did you learn in this module?
6. What did you like most about this module?
7. What did you like least about this module?

Data analyzed from these student surveys included the following six *Techtronics* Modules: Lego Robotics, Heart Monitors, Solar Energy, Bridges, Towers, and AM Radios. Data from all of the classes to which each module was taught was combined to create a larger dataset to gain statistical power and to afford comparison over 3 years. For each module, there are three class sets (except for Lego-Robotics for which there are six). To assess which *Techtronics* Modules most appealed to male and female middle school youth, comparisons were made between ratings of modules across gender utilizing independent- t-tests for questions 1-4 of the End-of-Module Survey. Results from these gender comparisons are presented in the tables that follow. No statistically significant differences between gender ratings for enjoyment or learning were found for the Bridges (n=34), the Solar Modules (n=49), or the AM Radios (n=39). Data for tests for which there were statistically significant differences is provided below.

Table 1 Comparison of Male & Female Ratings Legos-Robotics Module 2003-06

t-Test: Two-Sample Assuming Equal Variances

Lego-Robotics

Enjoyment	*Male*	*Female*
Mean	4.5417	4.2419
Variance	0.5514	0.6145
Observations	48	31
Pooled Variance	0.576	
df	77	

t-Test: Two-Sample Assuming Equal Variances

Lego-Robotics

Learning	*Male*	*Female*
Mean	4.3958	4.1290
Variance	0.5421	0.4495
Observations	48	31
Pooled Variance	0.5060	
df	77	

t Stat	1.714		t Stat	1.628
P(T<=t) one-tail	0.045		P(T<=t) one-tail	0.054
t Critical one-tail	1.6649		t Critical one-tail	1.6649

As predicted, males reported a statistically significant, slightly higher average level of enjoyment than females on the Lego-Robotics modules ($p \leq .05$) and also on learning from the module ($p \leq .05$). Since computer programming was a significant component of this module, this finding is consistent with research suggesting that boys have been found to show more preference for working on computers than girls[16]. These differences, while statistically significant, were relatively small with mean differences of approximately 0.3. Both males and females generally endorsed the statements that they enjoyed and learned from the Lego- Robotics Module. Further qualitative analysis of boys' and girls' assessment of this module follows in the next section. No significant differences were found between girls and boys on the Lego- Robotics Module for rating of instructors or difficulty of the module.

Table 2 Comparison of Male & Female Ratings EKG-Heart Monitor Module 2003-06

t-Test: Two-Sample Assuming Unequal Variances

Tech I EKG

Enjoyment	*Male*	*Female*
Mean	4.2800	4.6429
Variance	1.1267	0.2473
Observations	25	14
df	36	
t Stat	-1.4488	
P(T<=t) one-tail	0.078	
t Critical one-tail	1.6883	

t-Test: Two-Sample Assuming Unequal Variances

Tech I EKG

Learning	*Male*	*Female*
Mean	4.2800	4.7143
Variance	1.2933	0.2198
Observations	25	14
df	35	
t Stat	-1.6724	
P(T<=t) one-tail	0.052	
t Critical one-tail	1.6896	

Consistent with differences predicted based on the preceding literature review, girls rated the EKG-Heart Monitor Module slightly higher than boys (significant at $p \leq .05$) in terms of learning from the module. Although girls also rated this module slightly higher than boys for enjoyment, this difference was not statistically significant in this small sample ($n=39$, $p=.078$). These results are not surprising in that numerous researchers have found girls to prefer science and engineering enrichment programs that emphasize the human versus technological aspects of science, and biological systems[1,9] and this EKG-Heart Monitor Module is strong on describing use of this technology to benefit individuals as well as teaching functions and facts about the human heart. These differences, while statistically significant, were relatively small with mean differences of approximately 0.3 for enjoyment and 0.4 for learning. Both males and females both rated this module highly (mean > 4.2 on a scale of 1 to 5) indicating on the average that both genders enjoyed and learned from the Heart Monitor Module. There was no significant difference between gender ratings of instructors or level of difficulty for the EKG Module.

Table 3 a. Comparison of Male & Female Ratings Towers Module 2003-06

t-Test: Two-Sample Assuming Unequal Variances

Tech II TOWERS

t-Test: Two-Sample Assuming Unequal Variances

Tech II TOWERS

Enjoyment	*Male*	*Female*
Mean	4.32	4.55
Variance	1.06	0.2727
Observations	25	11
df	33	
t Stat	-0.8698	
P(T<=t) two-tail	0.3907	
t Critical two-tail	2.0345	

Learning	*Male*	*Female*
Mean	3.96	4.55
Variance	1.6233	0.2727
Observations	25	11
df	34	
t Stat	-2.2373	
P(T<=t) two-tail	0.0589	
t Critical two-tail	2.0322	

Close examination of data for the Towers Module revealed invalid data for one male subject that was eliminated prior to the analysis of data reported in Table 3 a. above. Although no predicted differences between boys and girls were made for the Towers Module, it was found that girls rated the Towers Module slightly higher than boys in terms of learning from this module though this difference was not statistically significant. This finding is noteworthy, however, in that it approaches significance at a two-tail probability level (p=.0589). Since there were no hypothesized differences between male and female ratings for the Towers Unit, a two-tail probability level was utilized to determine significance. Given that this finding approaches significance in this small sample, it will be worthwhile to examine it in future analyses with larger numbers of students. There was no statistically significant difference in terms of enjoyment between boys and girls for the Towers Module, though girls did rate it slightly higher than boys. It should be noted that both genders rated this unit very positively in terms of enjoyment (mean > 4.3 on a scale of 1-5) indicating general satisfaction with this unit.

Table 3b. Comparison of Male & Female Ratings Towers Module 2003-06

t-Test: Two-Sample Assuming Unequal Variances

Tech II TOWERS

Instructors	*Male*	*Female*
Mean	4.48	4.8182
Variance	1.1766	0.1636
Observations	25	11
df	34	
t Stat	-1.3588	
P(T<=t) two-tail	0.1832	
t Critical two-tail	2.0322	

t-Test: Two-Sample Assuming Unequal Variances

Tech II TOWERS

Difficulty	*Male*	*Female*
Mean	2.64	3.27
Variance	0.8233	0.4182
Observations	25	11
df	27	
t Stat	-2.3754	
P(T<=t) two-tail	0.02489	
t Critical two-tail	2.05183	

There were statistically significant differences ($p \leq .05$) between boys and girls on rating of difficulty of this module, with girls rating this module as “just right” on the average (female mean=3.27) and boys rating this module as a bit “too easy” on the average (male mean=2.64). Although these differences are statistically significant, the magnitude of these differences is small suggesting only small differences between males and females on this Module along the “too easy” “too hard” dimension. In addition, girls rated their instructors as slightly higher in terms of doing a good job teaching the module, but this difference was not statistically significant.

Although this module does involve some use of the computer (e.g. students learn Modelsmart 3D to design their own towers in this module with a focus on 3-D design and construction), this type of computer work is also consistent with what the literature suggests is engaging to girls when using computers as it provides opportunities for collaborative strategizing and involves design and creative aspects of programming [16,17].

After examining the data more closely, it was noted that one of the three class sets included for data analysis consisted of 13 males and only one female. This particular class had more classroom management issues and consequently may not have been as effective as other *Techtronics* classes based on feedback from a middle school teacher at the school. These classroom management issues may have been a result of that year's Engineering Teaching Fellows not being as skilled at management and teaching as in other years; or possibly, since this class was almost entirely made up of boys, students may have been more rambunctious than in a more gender balanced class set. Regardless, the mean response to enjoyment for this particular class was 3.8 while the mean response to learning for this class was 3.6. These values are lower than the values of the more gender balanced class sets combined, which had a combined mean of 4.6 for enjoyment and 4.3 for learning. As evidence that the Engineering Teaching Fellows may not have been as effective at teaching as the other classes, the mean instructor rating was 3.9 in the class with lower enjoyment and learning averages while it was 4.9 for the more gender balanced classes combined. Since the class with more behavioral problems consisted almost entirely of males, its effect is seen disproportionately in the lower male means. This disproportionate ratio of males to females combined with behavioral problems for that year may have contributed some to the difference in gender ratings for the Towers Unit. Due to these possible confounding issues in the data, the analysis was also conducted eliminating the data for this class with management issues to test for possible differences in the findings. When data was re-examined without this class, girls still rated this module slightly higher both on learning and appropriate level of difficulty, though these differences were not statistically significant with this 36% reduction in sample size.

Further evaluation of the particular aspects that contributed to boys and girls rating of the Towers module will be made by examination of the open-ended responses and individual interviews presented in the Qualitative analysis section to follow.

Table 4. Comparison of Male & Female Ratings -AM Radios 2003-06

t-Test: Two-Sample Assuming Equal Variances

Tech II AM Radios

Difficulty	*Male*	*Female*
Mean	2.3393	3.1818
Variance	0.7417	0.9636
Observations	28	11
Pooled Variance	0.8017	
df	37	
t Stat	-2.6444	
P(T<=t) two-tail	0.012	
t Critical two-tail	2.0262	

For the AM Radio Module, there were no significant differences between boys and girls on ratings of enjoyment or learning or instructors. With respect to level of difficulty, girls rated this module on the average as "just right" in terms of level of difficulty while boys rated it as a bit "too easy" ($p \leq .01$).

Qualitative Data Analysis and Results

For *Techtronics* Modules demonstrating statistically significant differences between boys and girls on ratings of enjoyment or learning (on the quantitative part of the 2003-06 End-of-Module Student Surveys as reported above), data from the open-ended questions from the End-of-Module Survey and from subsequent in-depth student interviews conducted at the end of the Fall 2006 semester were analyzed in an effort to better understand which factors contributed to differences between male and female ratings of modules, in terms of students learning, enjoyment of specific modules as well as what aspects of modules were least liked by boys versus girls. In addition, though the Towers Module did not demonstrate statistically differences between boys and girls ratings of learning and enjoyment at the $p \leq .05$ level, females rated it slightly higher than males on learning with a p-value approaching significance (two-tail $p = .0589$) so it was considered worthwhile to explore the qualitative ratings of this module by both genders as well. In addition, student recommendations for improving modules to optimize appeal to both genders were gathered.

Qualitative analysis techniques were used to: (a) analyze the open- ended student responses on the End-of- Module Student Surveys and (b) analyze information gathered from the student interviews. Qualitative analysis of exact student responses consisted of grouping together of conceptually similar student responses to three open-ended questions from the *Techtronics* End-of-Module Student Surveys. These questions are listed in the tables that follow along with the number of students responding in the different categories. Below the number of responses is the percentage of male or female responses respectively. Percentage of responses is the more appropriate comparison figure since there were differences in the number of male and female responses to each question. These qualitative results are presented to provide further insight into the preceding quantitative results.

Table 5. Qualitative Comparison of Male and Female Open-Ended Questions and Interviews for the Lego-Robotics Modules

Legos-Robotics 2003-06- What did you learn in this module?										
	Affective/ Motivation-al Aspects	Device Works	Gears	Program-ming	Building/ Design Sci/Eng Process	Robot Sensor	Humanized Aspects of a Robot	Interest/ Enthus-iasm	Science/ Engineer Terms	Real World Applica-tions
F	**2**	**1**	**2**	**4**	**7**	**3**	**4**	**1**	**0**	**0**
	8%	4%	8%	17%	29%	13%	17%	4%	0%	0%
M	**0**	**0**	**1**	**13**	**6**	**2**	**1**	**2**	**1**	**2**
	0%	0%	4%	46%	21%	7%	4%	7%	4%	7%

Legos- Robotics 2003-06- What did you like most about this module?										
	Affective/ Motivation-al Aspects	Racing/ Testing/ Challeng ing	Gears	Program-ming	Building Design/ Sci/Eng Process	Robot Sensor	Humanized Aspects of a Robot	Interest/ Enthus-iasm	Science/ Engineer Terms	Real World Applica-tions
F	**2**	**5**	**0**	**3**	**6**	**0**	**2**	**1**	**0**	**0**
	11%	26%	0%	16%	32%	0%	11%	5%	0%	0%
M	**1**	**7**	**0**	**5**	**10**	**1**	**1**	**1**	**2**	**2**

	3%	23%	0%	17%	33%	3%	3%	3%	7%	7%

Legos- Robotics 2003-06 What did you like least about this module?									
	Waiting	Problems with group members	Behavior Problems	Device Malfunc-tion	Legos	Tedious/ Repetitive	Computer Programm-ing	Crossword/ Learning about parts	Not winning
F	**4**	**6**	**0**	**3**	**1**	**0**	**2**	**1**	**0**
	24%	35%	0%	18%	6%	0%	12%	6%	0%
M	**0**	**3**	**2**	**4**	**0**	**1**	**0**	**3**	**4**
	0%	18%	12%	24%	0%	6%	0%	18%	24%

For the Lego-Robotics Module, which was rated slightly higher by boys than girls, both for learning and enjoyment (see preceding t-tests-Table 1), males mentioned programming the robots more than any other factor when asked what they learned during this module while the greatest number of female responses indicated that females reported most frequently learning about building and/or the engineering design process during this module. Consistent with the literature, this strong endorsement of programming by males could have contributed to boys' slightly higher (but statistically significant) rating for learning from this module over girls. Approximately the same percentage of boys and girls reported liking programming most in the module. Also consistent with this gender difference, two girls reported programming as a negative aspect of this module while no boys made a similar report.

As predicted by the literature, both genders reported that what they most liked about this module were the design and building aspects, with racing/testing and challenging their robots coming in second for both males and females. Further examination of specific responses indicated that girls reported enjoyment of racing but boys added the additional dimensions of winning and "battling the bots". Other features of this module appreciated by both genders included the fact that the robots could "dance and sing".

In terms of negative factors, girls reported waiting and problems with group members as negative aspects of the module and two girls also reported programming as a negative aspect of the module while no boys reported negative aspects of programming. These negative factors may have contributed to the lower female rating for enjoyment.

Based on individual interviews, comments regarding what most interested and excited girls about this module included "racing around the table and finding the spaceship (Mars Rover Module)", "trying to get to the spaceship", and "seeing it work on Mars". Boys comments about what most interested and excited them about this module included "when we got to test out how well our robots could do", designing, "battling the bots and going around Mars", and "all of it, freedom to build different designs and testing them out". When asked "*What parts of the module they would like to do more of*" girls comments included "more racing, bigger course, trying to figure out how to get the spaceship, and building, adding features to the car". Boys' answers to the same question included "construction, the whole thing, battling and adding more sensors".

Table 6. Qualitative Comparison of Male and Female Open-Ended Questions and Interviews for the Heart Monitor-EKG Modules

Heart Monitors 2003-06- What did you learn in this module?							
	Specific	Soldering	Engineering	Safety	Heart	College Life/	New Language/

	Engineering Science Content		Building Science Process	Issues	Function/ Medical Applications	Social	Terms
F	**5**	**6**	**5**	**1**	**5**	**0**	**1**
	22%	26%	22%	4%	22%	0%	4%
M	**4**	**7**	**4**	**2**	**5**	**1**	**1**
	17%	29%	17%	8%	21%	4%	4%

Heart Monitors 2003-06- What did you like most about this module?							
	Device Works	Engineering Building Science Process	Soldering	Group/ Team work	Instructors	Science/ Engineering Content	Trip to Duke
F	**0**	**3**	**11**	**2**	**0**	**2**	**0**
	0%	17%	61%	11%	0%	11%	0%
M	**1**	**9**	**12**	**0**	**1**	**0**	**1**
	4%	38%	50%	0%	4%	0%	4%

Heart Monitors 2003-06 What did you like least about this module?							
	Pieces Lost/ Device Malfunction	Problems with group members	Safety Issues	Too long/ Too much teacher talk/ Detail	Too short	Not winning	Heart game
F	**2**	**1**	**4**	**2**	**1**	**1**	**0**
	18%	9%	36%	18%	9%	9%	0%
M	**5**	**0**	**1**	**1**	**0**	**0**	**2**
	56%	0%	11%	11%	0%	0%	22%

For the Heart Monitor-EKG Module, which was rated slightly higher for learning by girls than boys (significant at $p \leq .05$) and for enjoyment (not statistically significant), the factor most often cited both for learning and enjoyment for both genders was soldering and with respect to learning from this module, heart function/medical applications had the second highest number of endorsements from both genders. For the second most liked feature of this module, both boys and girls again were in agreement in citing the engineering design/building process aspects of this activity. Again these findings are consistent with the literature concerning the importance of the hands-on building and tool handling aspects of engaging youth in STEM activities.

In terms of least liked features of this module, a high percentage of males (56%) reported problems with losing pieces or devices not working. It is possible that the problem of devices not working was more important to boys than girls and contributed to the slight difference in enjoyment. Since this module is not taught this year in *Techtronics* until second semester, no student interviews were possible this semester. However, past student comments about losing parts and having problems getting their monitors to work have already been addressed by the *Techtronics* team in that this module has been re-designed to feature fewer soldering points and fewer parts as well.

Table 7. Qualitative Comparison of Male and Female Open-Ended Questions and Interviews for the TOWERS Modules

TOWERS 2003-06- What did you learn in this module?								
	Engineering Building Science Process	Forces and Shapes	Safety Issues	Math and Coordinates	Real World Structures	Engineering/ Science content	Materials	Teamwork
F	**9**	**2**	**1**	**2**	**0**	**0**	**0**	**0**

	64%	14%	7%	14%	0%	0%	0%	0%
M	**8**	**7**	**2**	**2**	**4**	**3**	**3**	**1**
	27%	23%	7%	7%	13%	10%	10%	3%

TOWERS 2003-06- What did you like most about this module?								
	Engineering Building Science Process	Teachers	Graphing	Group work	Computer modeling	Engineering/ Science Content	Design	Crushing Structures
F	**10**	**1**	**1**	**1**	**1**	**0**	**0**	**1**
	67%	7%	7%	7%	7%	0%	0%	7%
M	**14**	**1**	**0**	**4**	**1**	**2**	**1**	**3**
	54%	4%	0%	15%	4%	8%	4%	12%

TOWERS 2003-06 What did you like least about this module?									
	Waiting	Measuring/ Calculations/ Graphing	Planning/ Designing	Problems with group	Safety Issues	Building	Not winning	Teachers	Tutorial
F	**1**	**2**	**3**	**1**	**1**	**1**	**0**	**0**	**0**
	11%	22%	33%	11%	11%	11%	0%	0%	0%
M	**1**	**2**	**0**	**2**	**3**	**1**	**5**	**1**	**1**
	6%	13%	0%	13%	19%	6%	31%	6%	6%

As previously noted, the Towers module was rated slightly higher (significant at $p \leq .05$) by girls than boys in terms of appropriate level of difficulty, and slightly higher (not statistically significant) on enjoyment and learning. Based on data presented in Table 7 above, the engineering design and building components of Towers was the most interesting part of this module for both genders. Specifically on the question of "What did you learn from this module," 67% of female responses cited the engineering building process compared to 27% of male responses, though this 27% was the most frequently cited learning aspect of this module for males as well. This factor is worth further exploration to understand any content/process learning difference between genders for this module.

In terms of enjoyment, more responses involving engineering design and building were cited than any other factor for both males and females. In terms of negative factors, the things students liked least about the module were diverse, but girls least liked the planning/design process and boys had more problems with not winning.

From their individual interviews, it was also clear that both genders learned a substantial amount from this module. One female student mentioned that her favorite part about ModelSmart 3D, the educational CAD package used, was "being able to build a tower and test it on the computer" as well as "turning computer design into real life". When asked in their interview *what they learned from Towers*, a subset of students' individual comments follow verbatim:

FEMALES (INTERVIEW RESPONSES ARE IN ITALICS)

- *A triangle is the strongest shape. (equal distribution, small triangle better, big base is good because it helps support the rest)*
- *I learned about 3 types of forces on tower. I learned how to construct a tower with balsa wood. (Compression is pushing in, tension is pulling out, tensile (torsion) is twisting, using model smart, determining angles and points, identifying coordinates)*

- *How to make buildings that won't break easily, Cartesian coordinates (x, y, z) for finding points for Model Smart, triangle is the strongest, learned to design in Model Smart*

MALES

- *I learned that teamwork was an important part of the project and that triangles are the strongest shape*
- *That big triangles/big shapes are the weakest-the triangle is the strongest but it has to be small; the big triangle broke fast. I also learned the Pythagorean theorem* $a^2+b^2=c^2$
- *I learned about the 3 types of forces put on a tower. They were compression, torsion, tensile. (3 types of forces-compression, torsion, tensile; strongest base is a small triangle because you can't push it together; large surface area is easier to push over; simpler towers seemed to hold up more weight)*

Discussion

Comparisons were made between gender ratings along two important dimensions (learning, enjoyment) and also for (efficacy of instructor and level of difficulty) for these six hands-on engineering modules (Lego-Robotics, Bridges, Heart Monitors-EKG, Solar, Towers and AM Radios) from the *Techtronics* after-school program for middle school students. Consistent with predictions based on review of literature for effective engagement of both genders in STEM after-school programs, boys rated the Lego- Robotics Module slightly higher both on enjoyment and learning, while girls rated the EKG Module slightly higher on learning. Since Lego-Robotics requires a substantial amount of computer programming, these findings are consistent with research suggesting that boys have been found to show more preference for working on computers than girls[16]. The slightly higher ratings by girls on the EKG-Heart Monitor Module is also not surprising in that numerous researchers have found girls to prefer science and engineering enrichment programs that emphasize the human versus technological aspects of science, and biological systems[1,9] and this EKG-Heart Monitor Module is strong on teaching the applications of this technology to benefit humanity as well as teaching functions and facts about the human heart. No statistically significant differences were found between gender ratings for learning or enjoyment for the Bridges, Solar, and AM Radios modules.

Further examination of qualitative data (students responses to open-ended questions about what they learned and most liked in these modules) was done to identify factors contributing to these gender differences. A striking degree of agreement was found between males and females as to possible factors contributing to learning and enjoyment for these modules for both genders. Both males and females most often cited *engineering design/building* when asked what they *learned and most liked for the Towers Module*, and both cited engineering *design/building most often* when asked what they most *enjoyed* about the *Lego-Robotics Module* as well. Though there were important differences between genders for what they learned from Lego-Robotics (*females cited engineering/design* most often and *males cited computer programming*) these differences were consistent with predictions based on the literature as described above. In addition a surprising commonality between genders was found for the second most cited factor contributing to their learning and enjoyment of the Lego-Robotics Module. Both boys and girls cited second most frequently examples of racing/testing/challenging when asked what they learned and enjoyed for this Module.

For the EKG Module, there was also agreement between boys and girls as to what they learned and most liked about this module. S*oldering* was most often cited by both for these two dimensions with learning about *heart functions and medical applications* coming in second for both. These findings suggest the importance for both genders of *having activities that allow students to work directly with tools* to construct their own projects and *inclusion of medical/human applications* as important features for engaging both male and female middle school students.

In this study results from questions 1 and 2 on the survey (rating of learning and enjoyment) were utilized to assess which modules students most enjoyed and which modules students felt they learned the most from. While self assessed learning is not the same as enjoyment or module preference, it would be logical to assume that a module from which students learn more has engaged students in some way and is therefore a possible indicator of preference. Self-reported enjoyment and student learning are used as indications of student engagement or preference for particular modules in this study and will be retained as measures for future analyses.

Assessment of impacts of constructs measured by survey questions 3 and 4 (rating of instructors and rating of difficulty along the "too easy-too hard" continuum) could prove valuable in understanding possible explanations as to why students reported learning more or more enjoyment from a given module.) For the Towers Module for example, differences between gender rating of this Module approached significance ($p=.0589$, two-tail) with respect to learning *and* girls also rated this module differently with respect to rating of difficulty ($p \leq .05$) when compared with boys. While the current sample was too small to test for possible interaction effects between these two variables (e.g. does level of difficulty of a module effect ratings of learning?), in future studies with larger sample sizes it would be important and possible to use ANOVA designs with all 4 survey questions (learning, enjoyment, efficacy of instructors, and level of difficulty) entered as independent variables to allow testing for main versus interaction effects. Similarly, class year could also be entered as an independent variable to assess for other possible confounding factors and possible interaction effects, (such as those mentioned for the Towers Module) and for differences between years with respect to such issues as classroom management, and the myriad of other variables not assessed in this study (such as whether or not students were allowed to choose their groups and how group dynamics a particular year effected student learning and enjoyment, etc). For future analyses with larger samples sizes, it will also be important to aim for balanced number of males and females in each class or include gender imbalance as a variable as well.

Summary and Recommendations

Data analysis for these six hands-on engineering modules (Lego-Robotics, Bridges, Heart Monitors-EKG, Solar, Towers and AM Radios) from the *Techtronics* after-school program for middle school students were presented. Despite the fact the engineering often has less female than male representation, this curriculum demonstrated high levels of enjoyment and learning for both genders suggesting strong endorsement by both male and female middle school students in this sample. Data analysis revealed small but statistically differences between genders for 6th and 7th grade middle-school students on the Lego-Robotics and EKG Modules. As predicted based on the literature, boys rated the Lego-Robotics Module slightly higher both on enjoyment and learning, while girls rated the EKG Module slightly higher on learning. Qualitative analyses were completed on open-ended questions and student interviews to better understand factors contributing to these differences in ratings between genders.

Consistent with research on gender preferences in the area of STEM education, the strongest factor contributing to boys' higher ratings over girls for learning during the Lego-Robots Module was the activity component of *programming* the robots. However, both genders rated highly the *design and building aspects* of the Lego-Robotics module indicating the importance in an engineering enrichment program of including *hands-on building and design features to engage both male and female students.*

For the EKG Module, the factor overwhelmingly cited as most appealing to and most often cited in terms of learning for both girls and boys was *soldering* with learning about *heart functions and medical applications* coming in second for both. These findings suggest the importance for both genders of *having activities that allow students to work directly with tools* to construct their own projects and *inclusion of medical/human applications* as important features for engaging both male and female middle school students.

Based on these findings and review of literature related to effective science and engineering after-school programs, recommendations for maximizing appeal and sustaining interest across genders include presenting engineering enrichment activities for middle school students in ways that demonstrate real-world human application and helpfulness of technologies in solving problems for humanity; utilization of biological applications of technologies; incorporating hands-on design and building including usage of tools and scientific equipment for constructing projects; engaging girls in the creative, design aspects of computer activities; and providing career role models through mentors of both genders sharing their passion about their careers. Soliciting parent involvement and community support (through such activities as Saturday demonstrations at the University and publication of a newsletter) could also be helpful to further learning outside of after-school. Additional strategies for effective engagement of both genders include encouraging both boys and girls to ask questions and brainstorm designs in teams so that they get to experience the excitement of sharing each others' ideas and design outcomes while giving each individual equal opportunity to do so.

Plans are underway to offer this exciting *Techtronics* after-school engineering enrichment program, featuring hands-on modules designed to appeal to both genders, to after-school programs nationally. Replication of these analyses will be conducted on a broader scale to continue identifying salient factors and refining this engineering curriculum to optimally engage both male and female middle school students.

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