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Gender Differences in 7th Grade Students' Interest in STEM After Participating in a Solenoid Instructional Unit

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Research indicates that women are generally underrepresented in science, technology, engineering, and mathematics (STEM) programs, with specific mention of consistently low growth levels in engineering (Kanny, Sax, & Riggers-Piehl, 2014). According to the National Center for Education Statistics, over the past 25 years, there has been only a slight increase (14% to 17%) in the percentage of women receiving bachelor's degrees in engineering (Aud, Hussar, Johnson et al., 2012) and only 11% of all engineers are women (National Science Foundation, Division of Science Resources Statistics, 2011).

Literature Review

Although female performance in STEM related subjects in elementary education are generally comparable to males or even higher (Stoet & Geary, 2018; Wang, Degol, & Fe, 2015), women are noted to have a higher exit rate in the science and engineering fields (Hunt 2016). Women's underrepresentation in engineering can be partly explained by dissatisfaction with pay, advancement opportunities, work conditions, hours of long work, family commitments (Hunt, 2016), perceived organizational support and occupational commitment (Fouad, Singh, Capaert, Chang, & Wan, 2016). To encourage more girls to consider engineering as a career, it is important to understand and track attitudes towards STEM and a STEM career. Determining when and if attitudes toward STEM differ between girls and boys is critical if we are to maximize opportunities for girls to participate in a STEM career.

Current studies suggest paradoxical findings: although STEM professionals are predominantly male, girls generally achieve higher grades in (k-6) mathematics classes when compared to boys. Higher grades in the early grades in school indicate ability for success in mathematics studies, a strong precursor of success in STEM careers, particularly engineering (Stoeger, Duan, Schirner, Greindl, & Ziegler, 2013; Wang, Degol, & Fe, 2015). Although girls receive comparable or even higher scores than boys in mathematics, there are questions as to whether girls have comparable affinity towards mathematics. Mathematics is a particularly critical subject area for those wishing to pursue coursework and a career in engineering.

This NSF ITEST funded research reviews the achievement scores and affinity towards STEM scores of male and female students after participating in a unit focused on understanding a solenoid. The unit is based on Constructivist Theory and uses project-based learning. Constructivists Theory suggests that humans construct knowledge and meaning from their experiences. Project Based Learning is a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge" (Buck Institute for Education, 2018, para. 3).

Methods

Participants. Student participants include 140 rural, seventh grade students participating in the Solenoid Invention Kit Unit Sequence during an in-school, science class. A school with similar demographics served as the control group. The unit was taught over a six-week period during spring semester 2017.

Solenoid Invention Kit Unit Sequence. The Solenoid Invention Kit curriculum contains five lab activities, two make activities, and one invent activity. These lessons are scaffolded to lead the learners from a baseline toward full mastery of the content and processes involved while working in small groups. Activities are iterative and the lessons are built around the principles of project based learning. Each lab activity is guided by essential questions and teaches key concepts and skills that are put to use in the labs and make activities. The final project of the unit is an invent activity, where all previous learning is put to use in a new and innovative ways.

Each phase of the project curriculum has a dedicated page with step-by-step instructions with photographic illustrations to guide teachers and students through the lessons and "make" activities:

> *Lab 1: Investigating magnetism.* In the first activity of the solenoid curriculum, students explore the concept of magnetism. The activities focuses on the properties of magnets. The students use a variety of materials, including copper, wood, and iron to experience magnetic fields and polarity
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> *Make Activity: Building a continuity tester*. Students embark upon their first make activity by learning how to solder wires. Students learn to a soldering iron. Finished products can be used to test electrical currents on following activities
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> *Lab 2: Investigating conductivity.* Students use the conductivity tester built in the first make activity to explore the properties of electricity. By placing the conductivity tester's electrodes on varying materials and watching for the illumination of the LED, the materials' conductivity can be ascertained. Differences found between the current as it passes through various materials helps students understand principles of electricity, including voltage, current, and resistance ("Solenoid Invention Kit," 2018).
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> *Lab 3: Detecting magnetic fields.* What is the relationship between electricity and magnetism? That essential question drives this lab as students use alligator clips, magnetic wires, batteries, and a compass to reenact Hans Ørsted's original experiment in which he discovered electromagnetic fields. According to the Make to Learn website, this specific activity is crucial as this discovery is the key to a number of following inventions in history
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> *Lab 4: Exploring electromagnetism.* The electromagnet is the driving force behind a solenoid, so students must first gain an understanding of the underlying principles. Since the solenoid is an essential part of many other FabNet Invention Kits, this activity is also very important to the scope and sequence of learning. Students explore how looping and coiling the wire affects the power of the electromagnetic field as measured by deflection of the compass first encountered in Lab 3.
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> *Make Activity: Building a solenoid.* This activity requires students to use parts that have been fabricated on the 3-D printer to build a working solenoid. It is suggested that students use this task as an introduction to computer-aided design (CAD) and computer-aided manufacturing (CAM) by designing and printing their own solenoid parts. However, the plans for the parts are available to download if the teacher prefers. Once the parts are completed, students coil wire around the solenoid frame.
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> *Lab 5: Investigating solenoids.* The penultimate activity leads the students through putting all the related knowledge and skills together to use coiled wire connected to a

battery on the 3-D printed solenoid tube to power a metal slug with the electromagnetic field. Hence, by this point, students have created a working solenoid that can be used to power a variety of different machines. The over-arching question of this activity prompts students to consider connections between the solenoid and modern-day inventions.

Activity: Invention activity. The culminating activity requires students to design and create a pop-up card that opens without being touched. Therefore, students must use their newly built solenoid to power the student-created opening mechanism of the card. Students have complete freedom in the design and structure of the card as long as it can be powered by an electromagnet ("Solenoid Invention Kit," 2018).

Instruments

Understanding a solenoid assessment. The solenoid test contains six items, each scored with a Likert scale rating of 1 to 3. This assessment was developed with NSF funding and measures students' understanding of a solenoid. The test consists of multiple choice items with corresponding descriptive responses. Previous uses of the test have indicated that increases in test scores occur as a result of participating in the solenoid instructional unit (Rutter, Standish, & Bull, 2016). For analysis of the assessment, a panel of experts developed a scoring rubric of descriptive responses. Content related validity was established through consensus agreement of a math professor, a science professor, a math teacher, and a doctoral student studying Curriculum and Instruction with a bachelors in engineering. Each member of the panel coded the results individually, and they convened as a group to discuss their decisions. Consensus was reached between all members on most questions, and notes of explanation were included for the few questions without consensus. Inter-rater reliability is reported at above .90.

STEM Semantics Survey assessment. The STEM Semantics Survey (Tyler-Wood, Knezek, & Christensen, 2010) was used to measure students' interest in science, technology, engineering and mathematics as well as interest in STEM careers. The survey is comprised of five scales, each with five items measured on a 7-point scale. The scores that are obtained when the instrument is scored are an inverted scale where a score of one indicates a very high affinity toward the STEM item and a seven indicates a very poor affinity towards the item. In the original study (Author, 2010), reliability estimates ranged from 0.84 to 0.93, which are considered to be "very good" to "excellent" (DeVellis, 2012). Internal consistency ratings for the five subscales from this data set ranged from 0.82 to 0.84, with an overall rating of "very good" (DeVellis, 2012). The instrument lists adequate content and construct validity (Tyler-Wood, Knezek, & Christensen, 2010).

Results

Understanding a solenoid scores. Achievement on the pre-post scores measuring gains in knowledge of the solenoid showed no differences between male and female students (see Table I).

Table 1

T-test Comparing Means of 7th Grade Girls and Boys on the Solenoid Test

	Gender	N	Mean	SD	Sig
Solenoid Unit	Male	84	3.75	1.77	.17
	Female	86	4.09	1.48	

STEM Semantics Survey. Gender differences in Affinity towards STEM and a Career in STEM were examined after implementing the solenoid unit. Using the STEM Semantic Survey, differences in scores were noted in affinity towards STEM (mathematics) with female students scoring higher when compared to male students. The STEM Semantic Survey is a reversed score assessment so high scores indicate low affinity.

Table 2

T-test Comparing Means of 7th Grade Girls and Boys on the STEM Semantic Survey

	Gender	N	Mean	SD	Sig
Science Subtest*	Male	88	13.92	5.38	.22
	Female	87	15.03	6.68	
Technology Subtest*	Male	88	10.13	5.62	.83
	Female	87	10.30	5.10	
Engineering Subtest*	Male	88	12.20	7.50	.26
	Female	87	13.45	7.17	
Mathematics Subtest*	Male	88	17.25	7.80	.05**
	Female	87	19.84	9.47	
STEM Career Interests*	Male	88	15.14	6.55	.62
	Female	87	15.35	6.43	

*=reversed scale, low numbers equal higher affinity towards subject area.

**=significant difference

Conclusions and Future Study

Clearly, it is important to identify and research factors that impact girls' decision to participate in STEM classes and careers. Curriculum needs to be examined to determine if it not only raises students' test scores but also provides a stimulus to pursue a career in STEM. Research documenting differences in achievement and attitudes towards STEM subjects need continued study. If differences are evident, it is important to determine when those differences occurred. Without an understanding of the differences in attributes of girls and boys in STEM areas, it is difficult to provide an equal learning opportunity for both groups.

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