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Including Children With Disabilities in STEM: An Outreach Program for Dyslexic Students (Research to Practice)

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(Research to Practice)

Strand: Other: Disabilities

Abstract:

Across the United States, educators are calling for improved instruction in science, technology, engineering and mathematics (STEM) at all levels, kindergarten through college. STEM is currently recognized as a critical area of knowledge for an educated citizenship. Despite educators' best efforts, however, some students are being left out of the STEM revolution because they have learning challenges in areas that are considered to be more important to their future success. One such group is students who are diagnosed with dyslexia, a learning disability that results in challenges when learning to read. These students often determine very young that they are not as capable in learning as their peers because they struggle to master reading. Yet, many dyslexic students are also gifted, and some researchers believe that some dyslexic students have a unique capacity to visualize in three dimensions, which ironically contributes to the challenge of mastering reading in two dimensions. The ability to reason in three dimensions is an advantage when learning STEM. This advantage should be recognized, developed and encouraged because many of these students may have the potential to be future scientists and engineers.

This paper describes a Colorado School of Mines' STEM outreach program, which focuses on the "E" in STEM (engineering concepts) and was delivered as part of the five week summer camp, Rocky Mountain Camp for Dyslexic Kids, in 2013. The target population included students in kindergarten through seventh grade who had been diagnosed with dyslexia and who were attending this summer camp, which was designed to support their learning needs with respect to reading. During the morning portion of this camp, students participated in intensive reading instruction. Two weeks of STEM units and three weeks of art units were offered as a "break" from reading instruction. All of the STEM lessons were designed to be haptic and to promote confidence and self-reliance in the students. The quantitative results, which include pre and post content assessments, support the effectiveness of the STEM component of the program. The qualitative results, which include letters of gratitude written by the dyslexic students, support the level of enthusiasm that these students had with respect to STEM learning. This paper shares both the quantitative and qualitative results and proposes future research concerning STEM and the dyslexic population.

Introduction:

Dyslexic students tend to struggle in their early elementary education, during which the primary focus is literacy development. Research suggests that dyslexic students' brains reason differently and process information differently when learning language from the brains of students who are not dyslexic[2, 3]. Additionally, certain studies suggest that dyslexic students favor peripheral vision rather than a centralized focus [4]. These differences often lead to difficulties in an elementary literacy programs that are designed for non-dyslexic children. Research on dyslexic learning, however, has led to the development of effective pedagogical methods for teaching reading literacy to dyslexic students[5].

These same brain differences, which cause dyslexic students to have trouble during early elementary literacy programs, could give them an advantage in STEM subjects, particularly engineering. In *The Gift of Dyslexia*, Davis and Braun (2010) observed that many dyslexic students innately approach problems from a three-dimensional perspective[2]. So when a dyslexic student is presented with an unfamiliar object, he may have a natural ability and predisposition to examine the object from various angles and perspectives in his mind, without ever moving himself or the object. The ability to reason three-dimensionally may lead a dyslexic student to be able to view the opposite side of an object in his mind, based on observations concerning the front of the object and his previous knowledge. This special reasoning skill is extremely useful in engineering. Language, however, is two-dimensional; the tendency to reason in three dimensions can lead a "b" to look like a "d", "p" or "q" if the viewing angle is flexible, as in the mind of a dyslexic, rather than fixed. These elementary literacy challenges that are possibly caused by three-dimensional reasoning must be controlled in order for a dyslexic child to learn to read. The approach, however, should permit the child to continue to view other objects in a dynamic, three-dimensional perspective, rather than a static, two-dimensional form.

In addition to enhanced three-dimensional reasoning capabilities, dyslexics may have enhanced capabilities associated with their peripheral vision bias. According to Schneps et al[4], the strong peripheral vision abilities that dyslexics display allow them to process information drawn from a broader than typical range of vision, while using less memory for processing that information. This can lead to fast "spatial learning" as evidenced by the performance of dyslexics on the contextual queuing and symmetry recognition tasks[4]. These abilities to recognize symmetry in a noisy picture and to locate a target amid a familiar background are extremely useful in observational sciences and engineering. Additionally, Schneps et al. cite the capabilities of dyslexics on the "impossible figures task"[4] or recognizing when a two dimensional drawing of a three dimensional figure would be impossible to actually construct in three-dimensions (e.g., the drawings of M.C. Escher). This research corroborates the research of Davis and others on the enhanced three-dimensional spatial reasoning abilities of dyslexics[2,4].

The peripheral vision and three-dimensional reasoning talents, which may be inherent to a dyslexic, may be lost entirely if a dyslexic student becomes too discouraged during his early elementary literacy education. Often dyslexic students feel different and dumb because of their struggles with learning language, and often they give up on themselves and their education at an early age. In fact, many young students who are diagnosed as dyslexic are also diagnosed as gifted[2]. These individuals who are often gifted and who have a unique ability to reason three-dimensionally need to be encouraged to develop their talents in the STEM subjects. According to http://www.happydyslexic.com/node/15, many famous scientists and inventors were or were probably dyslexic.

Camp Design:

The STEM outreach program was presented as part of the existing Rocky Mountain Camp for Dyslexic Kids, founded and directed by Joyce Bilgrave. The camp is a five-week summer program for students ranging in ages from 5 years to 12 years. The primary purpose of the camp is for students to receive one-on-one reading tutoring, using the Orton-Gillingham method of instruction, which has been researched and developed for over seventy years as a tool for teaching literacy to dyslexic students. During the morning portion of each day of camp, in addition to the one-on-one tutoring, students read aloud in small groups and write stories in the camp's computer lab. The STEM unit was introduced as part of this academic morning instruction as a reprieve from literacy instruction. An art unit was also introduced for this purpose. The afternoon of each day is devoted to learning outdoor skills such as equestrian skills, canoeing, rock climbing, etc. While much of the camp is designed to be fun and encouraging for the students, the literacy development portion is essential to achieving or maintaining a grade-level reading ability in these dyslexic students[3, 5].

While the camp is designed to be fun for students and to help them master literacy during their summer months off, the necessity of the extra literacy intervention can remind students that they are behind their peers in literacy, and this can be discouraging. The STEM unit was designed with lessons that were fun, encouraged independence in the students, and were particularly rewarding for students to complete independently. All lessons were designed to encourage students to reason in three dimensions, and to show them the usefulness of this skill as it applies to science and engineering. Since Davis and Braun (2010) and Eide and Eide (2011) believe that dyslexic students display natural aptitudes in STEM subjects, the STEM unit of the camp was designed to encourage dyslexic students in STEM areas[2, 3]. The unit illustrated to students that while they may have inherent struggles in some areas of instruction, they also have inherent talents in others.

For two weeks during the summer of 2013, the Trefny Institute for Educational Innovation at the Colorado School of Mines collaborated with this dyslexic camp to create and teach the STEM unit of the camp. The graduate students' efforts in this project were supported through an educational outreach grant provided by the American Physical Society. Additionally, two National Science Foundation funded projects contributed instructional units (DMR-0820518; EEC-1028968). The students at the camp were divided into four smaller groups of about seven students each, based on their age and reading ability. During these two weeks, for one hour each morning, each group of students would have a reprieve from their literacy instruction to complete a fun and encouraging STEM lesson. The lessons were designed to be given in one-hour blocks of time, and were adapted to the age and ability level of each group.

<u>Instructional Unit Design:</u>

For these two weeks, eight instructional STEM themes were explored by the students. Each lesson and each theme was designed to promote tactile learning, and to require little or no reading or writing on the part of the students. Lessons were designed to encourage students in STEM subjects and display their inherent talents, without reminding them of their challenges with language; posters and worksheets used in the STEM lessons were pictorial. All lessons were designed to have an independent, three-dimensional building component and to encourage students' confidence in their STEM abilities upon successful independent completion of the building and engineering components. These units provided students with the opportunity to be exposed to scientists and engineers in action and to recognize science and engineering as fun and rewarding. Below is a short description of each of the eight themes explored during the summer of 2013. Complete lesson plans are available upon request from the first author of this paper.

1. Water Purification (One Day of Instruction)

    a. Soil Filter Activity: Students poured water that had been ‘polluted’ with Cool-Aid, glitter and plastic bugs through a soil filter of sand, gravel and top soil. The Soil Filter Activity demonstrates how some pollutants in rain water get naturally filtered out as it passes through the soil to become ground water. This lesson required students to extrapolate three-dimensionally about what was happening in the middle of the soil filter from what they could see through the sides of the cup. The students also had the opportunity to speculate as to what would be an effective design for acquiring clean water when none was immediately available.
    b. Water Taste Test: Students performed a blind taste test on four cups of water, which had been purified using different engineering methods and determined if they could tell the difference between tap water, expensive bottled water, etc. Various methods of water purification were explained and the students explored their outcomes.
2. Paleontology (One Day of Instruction)
    a. Dinosaur Dig Lesson: Students dug chunks of plaster out of a box of sand and chiseled plastic dinosaur skeleton pieces out of each chunk of plaster. Next, they worked in pairs to put all the skeleton pieces back together and identify the type of dinosaur they found. The Dinosaur Dig Lesson demonstrated the difficulties and rewards of a paleontologist’s job. Also, this lesson required students to use the symmetry of the excavated pieces of skeleton to connect them in a meaningful pattern. Students had to take many symmetric objects and sort them; a skill supported by the dyslexic use of peripheral vision to process more data at once.[4]
3. Solar Energy (One Day of Instruction)
    a. Solar Cell Circuits: Students experimented outside with solar cell circuits; they could hook up the two solar cells either in series or parallel to either a fan or a few LED lights or both, and record their findings with each configuration. They used their experiments to propose and test an effective design for each purpose (i.e., turn on the fan, turn on the light, turn on both). The purpose of the Solar Cell Circuit Lesson was for the students to see how they could harness the sun’s energy to power everyday electronics.
    b. Expanding Balloon Activity: Students observed over the course of the morning both a white balloon and a black balloon, which had been blown up to equal sizes, to see what effect the sun’s rays had on them. The Expanding Balloon Activity taught students about the relationship between color and light absorption.
4. Hydrogels (Two Days of Instruction)
    a. Alginate Worms: Students squirted some sodium alginate into a bucket of calcium chloride solution and pulled out an Alginate Worm. The purpose of the Alginate Worms activity was to introduce the students to the idea of chemical bonding, hydrogels, and their many forms and uses. Students speculated and discussed the different engineering applications of these chemicals.
    b. Jell-O Strength Test: Students did a strength test on three different concentrations of Jell-O (half, normal, and double concentrations) by stacking washers on top of the Jell-O until it broke and recording their results in a bar graph. The Jell-O Activity was a continuation (from Alginate Worms) of our exploration of hydrogels and their properties.

    c. Water Beads: Students explored the behavior of expanding “Water Beads” (hydrogel beads often used in floral design) and the properties of the water beads before and after they had been introduced to water. This exercise required students to recognize shapes within a cup of water, even though the index of refraction was the same for both (they were the exact same color). These dyslexic students excelled at noticing the beads in the water immediately, due to the shadows cast by the beads on the periphery of the cup.

5. Lego Robots (Two Days of Instruction)
    a. Lego WeDo Robotics Lesson: Students individually designed, built, and programmed Lego robots. The students used the Lego WeDo Robotics kits to build their robots; the purpose of the Lego Robots Lesson was to demonstrate the rewards and difficulties of engineering hardware and software that work together to achieve a goal. This lesson put the students’ three-dimensional reasoning skills to the test, when they had to translate two-dimensional diagrams they had drawn at the beginning into building the three-dimensional figures of their robots. At the end, students had a sense of engineering accomplishment by independently building a working robot.
6. Human Heart (One Day of Instruction)
    a. Blood Pressure Demonstration: Students learned the difference between blood pressure and heart rate by observing the pressure exerted on a long balloon when fluid was being pushed through it, versus then the fluid was static. Then students measured their own blood pressures, and gained an appreciation for the importance of maintaining a healthy blood pressure.
    b. Stethoscope Lesson: Students designed stethoscopes out of funnels, balloons, and latex tubing. The purpose of the Stethoscope Lesson was to teach about heart health, how to measure heart rate, and what a healthy heart rate is. This lesson also demonstrated principles of sound amplification, transference and engineering, as it is applied to the health profession. These lessons gave students an appreciation for the direct application of the science and engineering that doctors use every day.
7. Hula Hoops (One Day of Instruction)
    a. Hula Hoop Lesson: Students started out with a slick black hoop (made of sprinkler hose) and discussed the forces acting on a hula hoop. They experimented with the hula-hoop and determined that a revised design was necessary, one which would increase friction. The students used duct-tape and their own design to increase friction on the hoop. This required spatial reasoning to produce a consistent pattern. Next, students experimented with different types of motion as they were using their hula hoops. The purpose of the Hula Hoop Lesson was to teach students about gravity, friction, angular momentum, centripetal force and design.
8. Foam (One Day of Instruction)
    a. Elephant Toothpaste: Students observed the chemical reaction between hydrogen peroxide, dish soap, and yeast. They learned what an emulsifier is and how soap works as an emulsifier that we use every day. They also learned about exothermic reactions, and that the foam is formed by the oxygen gas that is produced in the chemical reaction. Unique properties of foam were discussed, and the students

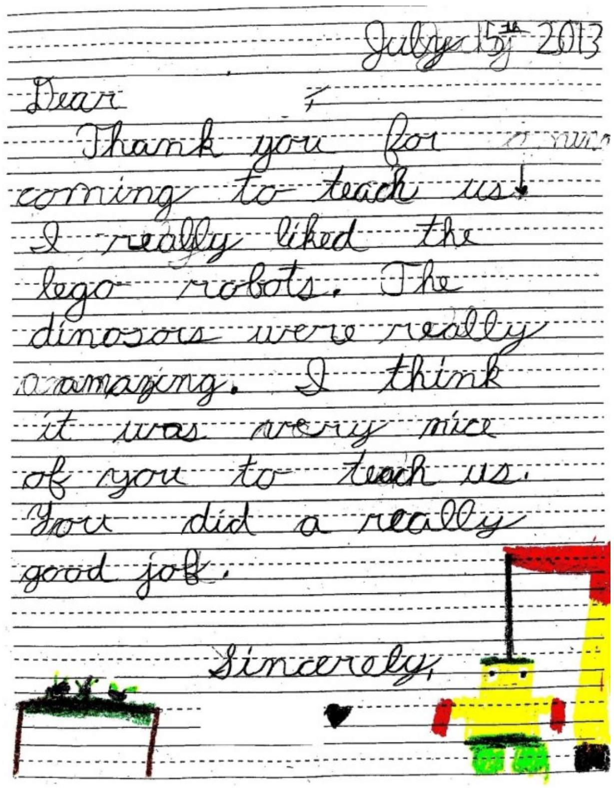
deduced how a three-dimensional volume of foam could form from layers of bubbles like the ones they could observe on the surface.

b. Root Beer Floats: Students observed the physical reaction that occurs when ice cream is shoved quickly into carbonated soda; this is the same reaction that causes the extreme amount of foam in the classic Mentos and Diet Coke experiment. Students discovered that the foam at the top of their Root Beer floats still had similar properties to the foam from the Elephant Toothpaste, but was formed by a different reaction from the carbon-dioxide gas.

At the end of the camp, students were also taken on a field trip to visit the Colorado School of Mines' campus. This trip included a Chemistry Magic Show and a tour of the CSM Robotics Lab.

Impact:

In the summer of 2013, both quantitative and qualitative data was collected. Qualitative data included letters of appreciation written by the students to the STEM unit instructors, like the ones displayed here. The importance of these letters should be recognized: dyslexic students' literacy challenges extend from reading the written word to writing the written word. Writing a story or even a short letter can be very challenging and time consuming for a dyslexic child. Figure 1 and Figure 2 are unsolicited letters or appreciation from dyslexic students who attended the camp in the summer of 2013. Figure 1 expresses the student's enthusiasm towards certain STEM lessons that were taught both within the prose and in the pictures that the student drew. In Figure 2, another student refers to the scientists who taught the STEM unit as "cool," an attitude towards scientists and STEM subjects that this student will hopefully keep throughout grade school.



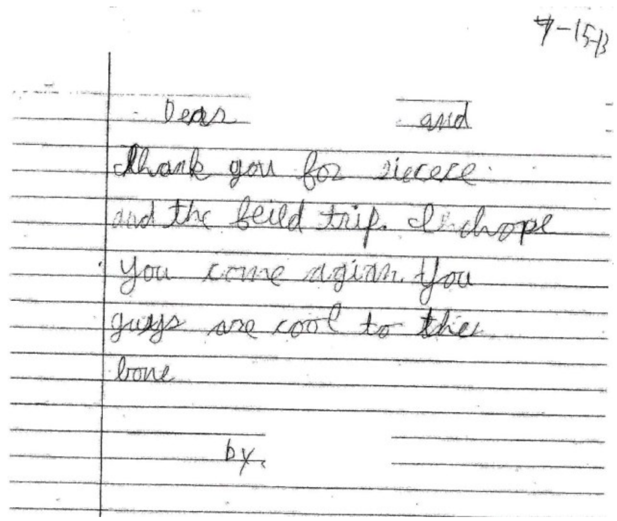
July 15th 2013

Dear

Thank you for coming to teach us! I really liked the lego robots. The dinosours were really amazing. I think it was very nice of you to teach us. You did a really good job.

Sincerely,

Figure 1



7-15-13

Dear and

Thank you for siecece and the feild trip. I hope you come agian. You guys are cool to ther bone

by,

Figure 2

Qualitative data also included drawings made by the students both on the first and last days of the camp. The instructions were "Draw a scientist." In this activity, students were asked to draw a scientist rather than an engineer because the typical elementary and middle school student has more experience and understanding, as well as stereotypes, with respect to science than engineering. Students drew what they thought a scientist should look like. Examples are displayed here. At the beginning, some drawings of scientists illustrated stereotypes, including lab coats (Figure 3), glasses (Figure 5, Figure 7), and physically obese males (Figure 5). By the end, many drawings had changed from the stereotypical 'mad scientist' to a person who looked more like the student drawing it. Some students, such as the student who drew Figure 4, even selected to make a note that 'anyone' can be a scientist. Figure 6 displays the student's perception of a scientist changing from an overweight person with glasses to a healthier person without glasses, who looked much more like the particular student who drew the picture. In Figure 8, the scientist has also lost the glasses and the wild expression, and looks much more like a happy child. These drawing demonstrated to us a change in attitude of some of the students towards scientists and themselves; a major benefit of this engineering outreach program for dyslexic students is to encourage them to put their talents to use in school in the pursuit of science and engineering, rather than becoming discouraged with school as a whole because of literacy. When dyslexic students associate scientists less with a non-relatable stereotype and more with themselves, they might begin to distinguish more between the struggle of literacy in school, which might seem like an insurmountable and distant summit, and the immediate success they could achieve in school within the STEM subjects.

Pre-Test

Figure 3

Post-Test

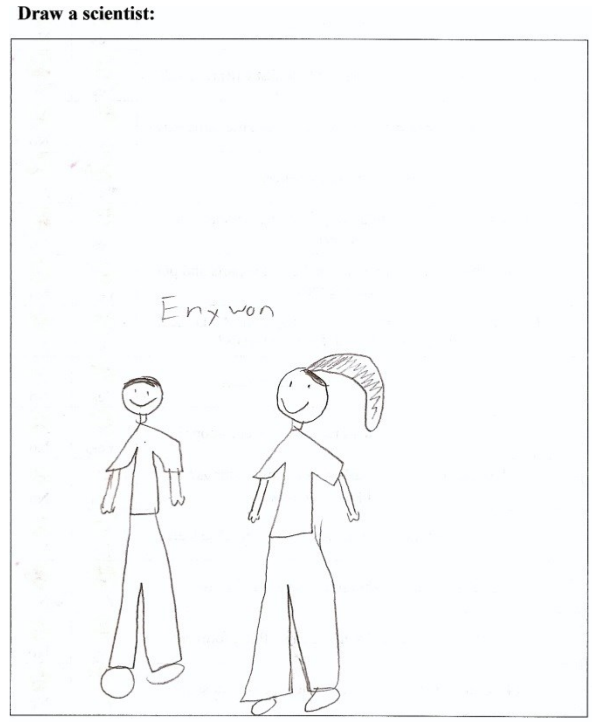


Figure 4

Figure 5

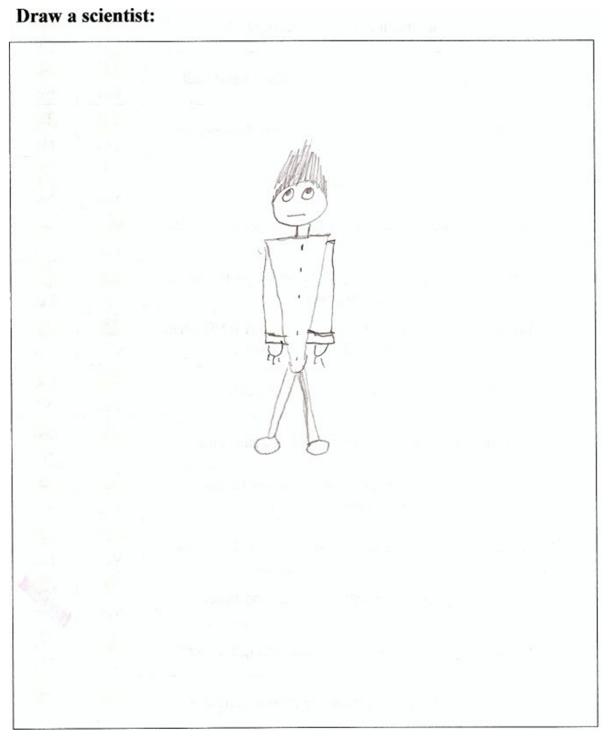


Figure 6

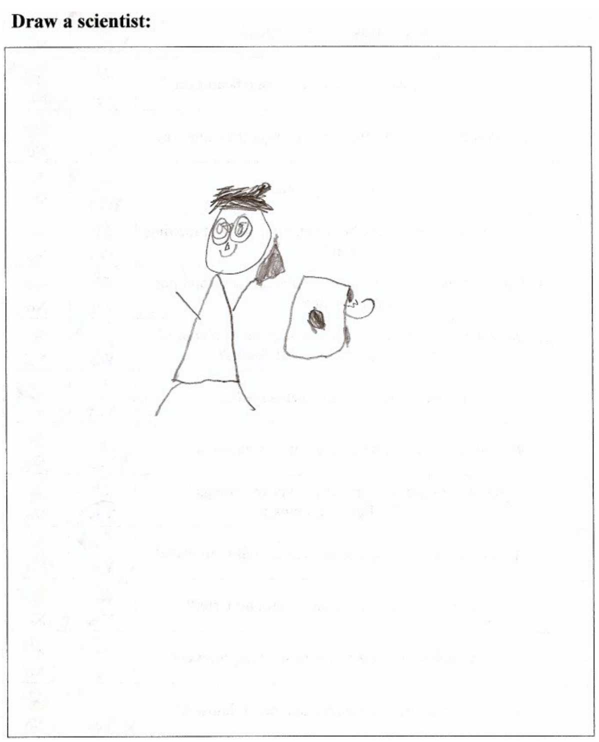


Figure 7

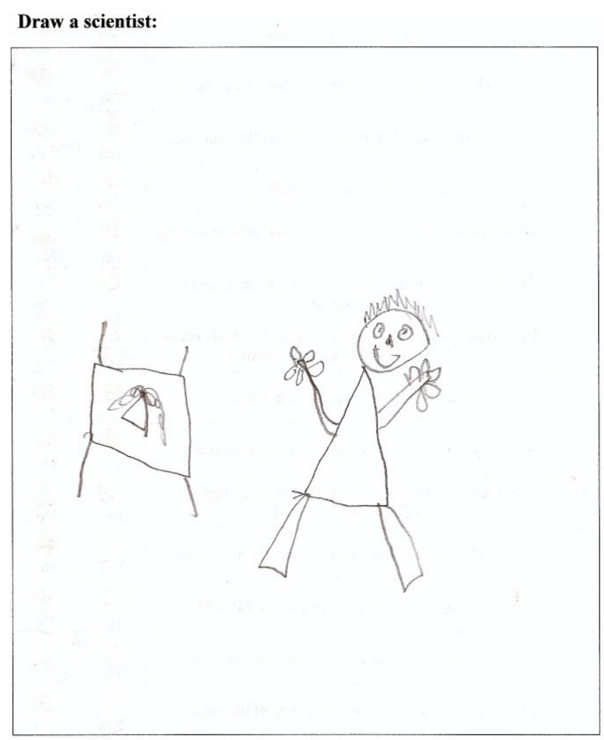


Figure 8

Quantitative data included pre- and post-tests on the content that was taught in each of the eight STEM themes. The tests consisted of fourteen yes-or-no questions, which were read aloud to the students and answered using either smiley or frowny faces. A smiley face indicated agreement and a frowny face indicated disagreement. Of the twenty-eight students who completed both the pre and post assessment in the summer of 2013, the majority displayed an increase in performance from pre- to the post-test, and none regressed. The average test score on the pre-test across 28 students was 9 correct responses out of 14 total questions; the average on the post-test was 11. On average, these 28 dyslexic students answered 2 more content questions correct after two weeks of STEM instruction. Using a paired, one-tailed t-test on the data, we obtained a p-value less than .001. Based on this p-value, we can conclude that there was a statistically significant increase in the students' performance from the pre- to the post-test. This data illustrates how quickly these dyslexic students learned the STEM lessons that were presented to them and how well they retained the information they learned.

Students demonstrated their understanding and enthusiasm about the STEM lessons to both camp and STEM instructors by asking insightful questions and having insightful discussions. Even kindergarten age students were able to explain the concept of angular momentum to camp instructors, and were eager to do so. Some students wanted to continue experimenting with the day's lesson at home and would ask to take home extra supplies for their experiments. Others would bring in their own science projects from home to show the STEM instructors. Attitudes toward STEM subjects were extremely positive among the dyslexic students, and many seemed to also gain personal confidence in these subjects as the camp progressed.

<u>Summary:</u>

The STEM community needs to encourage all students to develop and use their abilities in STEM; this effort should include students with disabilities. Unfortunately, many dyslexic students become discouraged and begin to see dyslexia as a broad-based learning deficiency at an early age. Yet, some researchers believe that dyslexia can provide a learning advantage in STEM fields and many dyslexic students are gifted. Interest in STEM learning needs to be encouraged at a young age for all students, but especially for those with dyslexia. Dyslexic students need to discover their talents in STEM before their literacy challenges discourage their desire to learn. Many dyslexic students are highly capable of pursuing STEM studies as young adults; few ever have the opportunity to discover that learning in the STEM fields is different from their early challenges of learning to read. Eighty percent of diagnosed learning disabilities are dyslexic diagnoses[1], and this significant minority population is often overlooked by STEM outreach programs.

This paper has outlined an effective approach for providing STEM outreach to dyslexic students. These students were given the opportunity to experience success in STEM, and to gain the confidence they need to overcome their elementary literacy challenges through early reading interventions. Camp participants showed measurable aptitude and enthusiasm towards STEM lessons, and were inspired to persevere in their learning. Future papers will continue to document our efforts to inspire and provide STEM success to the dyslexic mind.

<u>Dedication:</u>

We would like to thank the Trefny Institute of Educational Innovation, the National Science Foundation (DMR-0820518; EEC-1028968), and the American Physical Society for supporting

this outreach program. We would also like to thank the young children that attended this camp. We are interested in your future and we invite and look forward to your contributions to STEM.

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