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Increasing Diversity in Engineering: A K-6 Summer Outreach Program for Dyslexic Children

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Abstract:

It has long been recognized that the advancement of engineering and science requires the participation and contributions of a diverse group of well-trained professionals. Outreach activities designed to increase diversity often focus on drawing more women and minorities to these fields. Far fewer interventions have been developed with the purpose of attracting students with disabilities to these fields.

This paper describes a pilot implementation of a summer intervention in engineering and science that was completed in a kindergarten through sixth grade camp: The Rocky Mountain Camp for Dyslexic Kids. All participating students were diagnosed with dyslexia or dyslexic tendencies (borderline dyslexia). Forty-two students attended this five-week camp, with the primary purpose of improving their reading skills. The camp consisted of a four-hour morning segment in which the students received one-on-one reading instruction, one-on-one reading oral practice, writing instruction and a hands-on science or art unit. The science units were designed to use active learning techniques, which are known to be effective across various subpopulations including children with disabilities. This paper addresses the reason for targeting dyslexic students for a science and engineering intervention and the design, development and implementation of this one-week science unit in 2012.

Introduction:

Researchers (Davis & Braun, 2010; Eide & Eide, 2011) have found that children with dyslexia reason differently with respect to language from students who do not have dyslexia. They have further discovered that dyslexic students' brains process information differently with respect to language than do students without dyslexia. These brain differences have been identified and have resulted in the development of pedagogical techniques that are designed to support dyslexic students as they master language (Shaywitz, 2003).

Some researchers speculate that these brain differences, which result in challenges to language development, provide dyslexic students with an advantage in science. According to Davis and Braun (2010), in "The Gift of Dyslexia", many dyslexic students naturally use three-dimensional reasoning as a technique for problem solving. When dyslexic students encounter a problem solving situation, they naturally change their three-dimensional perspective and examine the problem from various angles without shifting their observation point. Many dyslexic students spin an object mentally without needing to alter how they are viewing that object. This skill of shifting perspectives is useful and effective in physical science; however, in two-dimensional language, changing a three dimensional perspective can result in a "b" looking like a "d", "p" or "q", depending on the angle at which the object is viewed. It is possible that the reasoning skill that results in language challenges for the dyslexic student provides them with an advantage in science and engineering.

This advantage may be lost or discouraged in the early elementary years because of the intense emphasis that is placed on literacy development. Many dyslexic students learn through their early elementary education that they are different and that they are dumb. Yet, dyslexia is not predictive of a student's level of intelligence. Many students who are diagnosed as being dyslexic are also diagnosed as being "gifted" based on standardized tests for intelligence (Davis & Braun, 2010). In fact, there are many recognized scientists and inventors who are believed to be or have been dyslexic, see: http://www.happydyslexic.com/node/15.

Developmental Profile of a Dyslexic Child:

This section provides the developmental profile of one dyslexic child. This example illustrates the potential scientific and engineering talent that can be hidden by a dyslexic diagnosis. This young girl, "Susie," is now seven and has been diagnosed as both "gifted" and "dyslexic." Notice in the discussion that follows her intelligence becomes less apparent as she enters elementary school, because her disability comes to the forefront of her education and her teachers' concerns.

- At the age of 2.5 years, a babysitter asked Susie to stop spinning in circles because she would become dizzy, and that would cause her to fall to the ground. Susie corrected her babysitter and explained that it is gravity that pulls us to the ground—being dizzy simply prevents us from having the balance necessary to resist gravity.
- At the age of 3 years, Susie told her mother that they were driving on an asteroid. Her mother laughed at this assertion and asked Susie to explain. Susie told her mother that back when the "Big Bang" occurred, the earth was an asteroid that was shot off from the sun. That asteroid was caught in the sun's gravity, as were others, creating what we now call the universe.
- At the age of 4, Susie told her mother that all of the earth's energy comes from the sun. Her mother asked how this could be true. Susie explained the transfer of the energy from the sun to the plants, to the animals and then to people. When asked about the energy that is stored at the center of the earth, Susie indicated that this came from the sun too—during the Big Bang.
- At the age of 5, Susie did not learn to read at the same rate as her peers. Her kindergarten teacher raised concerns. Science was not an emphasis of class and discussions began as to whether Susie should remain in kindergarten for another year. Her mother had her intelligence tested. Susie is gifted.
- At the age of 6, Susie continued to struggle in reading and was tested for a disability. Susie is dyslexic. The early advances that Susie displayed in science were no longer apparent. Susie's teachers argued that she should repeat the first grade. This was inconsistent with the recommendations of disability experts, as repeating a grade can be devastating to an intellectually gifted child and does not address the underlying challenge of dyslexia.
- At the age of 7, Susie is receiving one-on-one tutoring each week and attended the summer camp for dyslexics in 2012. Susie is reading at grade level. Science is still secondary in Susie's education because literacy is the primary focus of elementary education.

Susie's pattern of early intellectual advancement in science *before* starting her formal education, followed by repeated learning struggles in early elementary grades, is common for dyslexic students (Davis & Braun, 2010). Unfortunately, many of these students develop an expectation of failure before the fourth grade (Davis & Braun, 2010; Eide & Eide, 2011; Shaywitz, 2003). The purpose of the intervention described in this paper is to deliver the following message to dyslexic children: *You may have to work harder in the early elementary years to master language, but you have the potential of being a scientist or engineer in the future. We are here to help you retain and develop that potential.*

Camp Design:

The Rocky Mountain Camp for Dyslexic Kids was founded by Joyce Bilgrave who is also the current camp director, and is a five-week summer camp for dyslexic students in grades kindergarten through sixth. Although a fee is charged, this expense is used to off-set the cost of one-on-one reading tutors and afternoon activities. Each morning, the first four hours of camp are dedicated to academic instruction; the final four hours include outdoor pursuits, i.e. rock climbing, boating, hiking, horse riding etc. During the first four hours, the students participate in one-on-one tutoring, reading aloud in small groups, writing, keyboarding and a study session (see: http://www.rockymountaindyslexiccamp.org/node/5). Based on the Orton-Gillingham method of reading instruction (which has been researched and developed for over seventy years), these elements of the camp are necessary to ensure the reading advancement of dyslexic students (Shaywitz, 2003; Eide & Eide, 2011). All tutors in the camp are trained to use the Orton-Gillingham method of reading instruction.

The same interventions that eventually allow these students to master literacy can also remind dyslexic students that they are not learning to read at the same rate as their peers. The purpose of this intervention was to implement instructional units in science and engineering that are fun, interactive and rewarding to complete; they also were designed to capitalize on what many dyslexic students do well: reason in three dimensions. The goal of this intervention was to provide dyslexic students an opportunity to excel in science and engineering while receiving the appropriate remediation in literacy. According to Davis and Braun (2010) and Eide and Eide (2011), science and engineering are areas in which many dyslexic students display their natural talents.

In the summer of 2012, the Colorado School of Mines collaborated with camp instructors in the creation and implementation of science units that were included as part of the camp program. These units were implemented over the course of a week, in one hour daily sessions. There were four groups of students (10 or 11 per group), arranged by age. The instructional units were designed to be implemented in one-hour sessions and were adaptable to different age groups.

Instructional Unit Design:

Over a one-week period, five instructional engineering and science units were developed and delivered. Each day of the camp had a scientific theme. All of these lessons were designed to promote a haptic learning style, and to minimize or eliminate the need for reading or writing on the part of the students. The purpose of the science units was to stimulate interest in science and engineering without reminding the students' of their literacy challenges. All explanations were provided using visual posters, which were comprised almost entirely of illustrations. Each lesson focused on building three-dimensional objects individually, to encourage the students' already strong sense of spatial reasoning, and to build self-reliance and confidence. Each lesson was adapted to the appropriate age group for the hour. Below is a brief description of each day's activities for the summer of 2012.

Day 1: Biology (recycling and conservation)

The week started with an activity in which the students built planters out of newspaper. During the activity, they engaged in a discussion about decomposition and the definition and merits of biodegradable substances. Students planted watermelon and bean seeds, and discussed the responsibility involved in caring for their plants for the duration of the week. Later, students discussed the resources needed by people, animals, and plants. They explored the idea of limited resources, including how resources become limited and the impact of that limitation. The students participated in an activity about Prairie Dog overpopulation, in which they were deprived of their 'habitats'.

Day 2: Electromagnetic Spectrum

This unit began with a discussion of recycling and the importance of recycling for maintaining a healthy environment. This was followed by a discussion of electromagnetic waves and the difference in these rays in indoor and outdoor light. Students were then given recycled materials, i.e. old CDs and paper, and built a Spectroscope from these materials. They used their spectroscopes to investigate various sources of lighting at the camp.

Day 3: Solar Energy (types and uses)

Participating students learned about various energy sources, how energy is generated and how energy is used. Using this knowledge, they built a solar oven and baked smores as a classroom activity. Examining the smores in different ovens, they were able to compare the angles of their solar reflector and determine the impact of angle on the effectiveness of their oven. The students also learned about the EM spectrum. After this they were given beading string and UV Beads and made beaded bracelets. They used their bracelets to experiment inside and outside, with sunscreen and without sunscreen. The impact and importance of protecting themselves from UV rays was discussed. Students were able to take home both their solar ovens and their UV bracelets.

Day 4: Non-Newtonian Fluids (Cornstarch and Water)

The day began with a discussion of the states of matter and the attributes of a solid, a liquid and a gas. Next, the students discussed how a non-Newtonian fluid is different from other liquids, as it can turn solid under pressure rather than only by a change in temperature. The students watched a demonstration of a non-Newtonian fluid rapidly transforming between a liquid and a solid by the percussive action of a speaker, and the students discussed how different types of music might affect the way the fluid moves. Next, students explored the properties of the non-Newtonian fluid themselves in bowls and experimented with applying different types of pressure with their hands. Lastly, the students conducted a similar exploration with their feet by running across a long tub of the non-Newtonian fluid, and compared the results to when they simply stood still. Emphasis was placed on the scientific method and on the importance of hypothesizing before experimenting.

Day 5: Water (water cycle, pollution and purification)

The final day started with a discussion of the water cycle; the definition was followed by a review of the limited resources discussion and how water is an extremely valuable limited resource. A discussion followed about non-renewable resources and the importance of and difficulties involved in water purification. To reiterate the processes involved in the water cycle, the students watched a demonstration of water evaporating and condensing into a cloud in a jar. Next groups of students created edible aquifers while the rest of the class filled in coloring sheets about the water cycle. Students were asked to identify the aquifer on their coloring sheets, and there was a concurrent discussion about the importance of unpolluted aquifers and pure well water.

A more complete description of the Spectroscope activity is provided in the Appendix of this paper. Lesson plans for the remaining activities are available upon request from the first author of this paper.

Impact:

This program is in its early stages of development. As such, a formal assessment program is in the process of being developed. The future assessment plan will include evaluations of the students' attitudes toward science and engineering, the knowledge development in these areas and students' self-reports of attitudinal change with respect to science and engineering. For the pilot program that was implemented in the summer of 2012, however, only informal and preliminary methods were used to determine impact.

Based on the observations of both the camp and science instructors, the participating students expressed enthusiasm for the science units and a desire to continue their science investigations throughout the day. Students stopped by the science room in the morning, before the start of camp, hoping to "sneak a peak" at the day's lesson. Many of the students were reluctant to leave when the class was over and some students returned to the class throughout the morning to witness the experiments of the other students. Almost all of the students were eager to take their science experiments home and show their parents. Parents frequently stopped by the science room, expressing their child's enthusiasm for the science activities. Based on parental requests, the science team has been invited back to present two weeks of science lessons during the 2013 summer camp.

Each day, the camp instructors were surprised by the insightful questions that the students asked. This was true even at the kindergarten level. Six year old children were witnessed discussing photosynthesis and overpopulation. These students enthusiastically expressed hypotheses and proposed experiments to test their hypotheses. Every student at the camp was successful in completing each day's science experiment. Student attitudes with respect to science and engineering were consistently positive throughout the camp and appeared to become even more positive as the camp progressed.

Summary:

Over the past several years, the scientific and engineering community has recognized the importance of increasing diversity in its contributors. These efforts have primarily focused on females and minorities. The intervention described in this paper differs in that the target population is a group of elementary children who have a disability, dyslexia. Dyslexia comprises eighty percent of diagnosed learning disabilities (Carnine, 2003). Given the widespread occurrence of dyslexia in school age children, outreach programs designed for dyslexic children have the potential of significantly impacting the future population that comprises scientists and engineers.

In the past, dyslexia was thought to be a brain defect (Shaywitz, 2003) that interfered with a students' ability to learn to read. More recently, researchers (Davis & Braun, 2010; Eide & Eide, 2011) have come to understand dyslexia as a brain difference which presents challenges in language development but which may enhance three-dimensional reasoning. There are many successful scientists and engineers that are known to have dyslexia (http://www.happydyslexic.com/node/15). Unfortunately, many dyslexic students give up on learning based on an early educational system that emphasizes literacy, the area in which dyslexic students struggle (Davis & Braun, 2010; Eide & Eide, 2011). As was illustrated through the experiences of Susie, many of these students' natural talents in science and engineering are hidden from themselves, their parents and their teachers because they struggle to learn to read. These students often incorrectly conclude (as do others) that they are dumb rather than different.

This paper presents an alternative approach. Through a collaborative effort of the Colorado School of Mines and The Rocky Mountain Camp for Dyslexic Kids, young dyslexic students have the opportunity to explore science, an area in which many of these students excel. Although the primary emphasis of this camp is remediation in reading, the inclusion of science and engineering has provided these students with the opportunity to experience success. Camp participants are learning a new message; one that includes hope, inspiration and potential for success in the future.

To date, our assessment efforts have been informal. We have witnessed the enthusiasm and excitement with respect to mathematics and science in camp participants. Additionally, based on the requests of parents, we have been asked to increase our participation in this camp from one week to two weeks. Although these are positive indicators as to the impact of our effort, more formal methods of assessment are planned for the summer of 2013. This paper reports on the initial pilot results of our outreach program. Future papers are anticipated that report on the implementation of our formal assessment plan.

Bibliography:

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Appendix: Spectroscope Lesson

Adapted From:

http://littleshop.physics.colostate.edu/onlineexperiments/CD_Spectroscope.html

Objective:

To introduce the spectrum of electromagnetic waves that our sun emits by studying the spectrum of visible light, and by separating that spectrum into its component parts via a spectroscope.

Materials:

- Black cardstock
- Cd's
- Tape

Procedure:

1) First, lead a discussion about the electromagnetic spectrum: where do all of these waves come from? Do we get all of the waves that the sun shoots at us, or are some of them blocked? Can we sense all of them? (Some animals can 'see' infrared or ultraviolet—what would it be like to be able to see 'extra colors'?) What do we use them for? Why does the spectrum of visible light go from red to purple? (This discussion could be deepened to include the meaning of wavelengths for older students, or this part of the discussion could be cut out for younger students.)

2) Next, discuss visible light and how our eyes are able to perceive color: an object reflects certain light waves, and absorbs others. Our eyes pick up the ones that are being reflected. 'White' is when all the colors are reflected, and 'black' is when all the colors are absorbed. Ask the students which color t-shirt they would rather be wearing on a hot day.

3) Lastly, talk about what a spectroscope is: sure, you can see rainbows when you hold the shiny side of a CD up to the light, but how can we refine those rainbows into a perfect strip that demonstrates the spectrum?

4) Now each student gets four pieces: a recycled CD, a piece of cardstock cut in half length-wise with a notch on the edge of one of the halves, and half a piece of cardstock cut horizontally, with cuts and folds to allow them to make a box, and a slit on one side. (See the Little Shop of Physics website for more precise specifications.)

5) Each student tapes the two long pieces together to make a longer piece, wraps them around the CD and tapes them into a cylinder, and then tapes the CD shiny side up to the bottom of the cylinder with the notch against the edge of the CD.

6) Next, they fold and tape the boxes, and put the boxes covering the open end of the cylinder, with the slit in the box lined up with the notch in the bottom.

7) Once this is all taped together, turn off the lights, and have the students work in groups with a flashlight to see the spectrum. Shining the flashlight in the slit at the top and looking through the notch at the bottom gives the best result.

8) Encourage the students to take their spectroscopes with them and test different types of light. Does the spectrum look different when in sunlight as opposed to black light or a colored flashlight?