Enhancing Access and Fostering Science, Technology, Engineering and Math (STEM) Using Civil Engineering Materials Applications for Special Learning Disabilities Middle School Students

Craig Menzemer
Associate Professor of Civil Engineering, The University of Akron, Akron, OH 44325-3905 ccmenze@uakron.edu

Paul Lam[1], Julie Zhao[2], Jiang Zhe[3] and Dennis Doverspike[4]

Abstract - **For the past fifteen years, the United States has been faced with a steady decline in the number of students who are interested in the study of Science, Technology, Engineering and Mathematics (STEM). According to the study [1] of the four million high school sophomores in 1977, only 750,000 indicated an interest in science and engineering. This number further declined to 340,000 college freshmen who declared science or engineering as a major in 1980, and only 206,000 baccalaureate science and engineering degrees were awarded in 1984. Of these, only 46,000 received Master degrees in 1986 and approximately 9,700 Ph.D. degrees were granted. The picture is even bleaker for new college entrants in the next millennium. To increase the pool of students interested in STEM careers, it is important to develop programs capable of tackling disparities in STEM education and to provide a means of alleviating these problems. The purpose of this paper is to describe, summarize the findings and assess the first year summer and Saturday academic year STEM workshop programs for special learning disabilities (SLD) and typical middle school students. Exciting hands-on activities based on the Society of Automotive Engineers' "A World in Motion", smart balloon, civil materials, and information communication technology are designed to spark and capture the interests of participants in the STEM fields. In this paper the Civil Engineering curricula and hands-on activities presented at the workshops will illustrate aspects of inclusive technology and engineering classroom education that will help the students succeed. Data obtained from the participants and their parents via various surveys were used in the analysis.**

Index Terms – SLD, students, materials, workshops

INTRODUCTION

Special learning Disabilities (SLD), ethnic minority and female students remain underrepresented in a number of occupations, including those that might be classified as high-technology areas. Science, Technology, Engineering and Math (STEM) are the primary disciplines in which they have been traditionally underrepresented. The Enhancing Access and Fostering STEM Program for specific learning disabilities students is a National Science Foundation (NSF) Research in Disabilities Education Focused Research Initiative (RDE-FRI) funded program at The University of Akron. The program is the first such program in Northeast Ohio and will provide educational opportunities designed to motivate and support SLD and typical middle school students in the STEM fields. The three major objectives of this pilot project are: 1) encourage SLD and typical students to explore STEM as a future career choice by building their confidence and self efficacy in STEM, 2) develop empathy and better appreciation of diversity amongst students who would traditionally enter engineering programs and 3) develop understanding, better appreciation of diversity, and an elaborated sense of teaching and learning amongst the participants.

Social cognitive theories [2] recognize that learning experiences shape self-efficacy beliefs and outcome expectations, which in turn, affect the formation of vocational interests, which subsequently influence occupational goals, choice actions, and performance attainments. According to a comprehensive literature review of 66 reports involving science education for students with disabilities [3, 4, and 5], knowledge and learning are facilitated through providing activities-oriented science curricula, which can produce powerful learning and affective effects for students with SLD [6]. Thus, we propose that the use of hands-on educational activities will lead to better learning for students with SLD. The main hypothesis to be tested by this project is that providing intensive summer and Saturday academic year workshop experiences involving hands-on exercises will lead to increased self-confidence, self-efficacy, and career interest in the areas of STEM among SLD and typical middle school students. A typical student is defined as a student without an identifiable SLD or physical disability. In particular, this paper summarizes the findings, describes and assesses the first year summer NSF STEM Civil Engineering curricula and hands-on activities workshop for SLD and typical middle school students at The University of Akron. Data obtained from the participants and their parents via various surveys were used in the analysis.

DESCRIPTION OF THE SUMMER AND SATURDAY ACADEMIC YEAR WORKSHOPS

Participants of the program are middle school students with SLD and typical middle school students from sixth to eighth grade. During the first year of the program, 26 students were recruited, and included 11 students with SLD and 15 typical students. Of the students participating, 38% were underrepresented and 42% were female. Students were broken into six teams, each with a teacher a college student mentor. For hands-on experiments, students worked in groups of 2 SLD and 2 typical students, 1 college student mentor and a science/special education teacher. Teachers had the role of overseeing group activities and to make observations on student interaction within their group. Both the college student mentors and teachers were given the task of keeping all students within a team involved in the workshop activities.

One innovation of this project was the development of summer and Saturday academic year civil engineering material STEM workshops that exposed the SLD and typical middle school students to hands-on projects in engineering and science. The summer program provided both lectures and hands-on experience in STEM curricula. Another uniqueness of our approach was the presentation of the material in a simplified, but unified manner that linked mathematics to the understanding of science and engineering disciplines. It also integrated several engineering disciplines, which emphasized the inevitable interaction among these subjects in our everyday life. Working in a diverse group builds empathy and understanding amongst peers. Each hands-on activity allowed students to explore, probe, observe, collect data and investigate. The goal was not only to build middle school students' self esteem, but also to increase the awareness of college students, teachers and professors without disabilities so that they understand the capabilities of the SLD population in the STEM fields.

From the summer and Saturday academic year workshop experiences, participants obtained a sense of the intellectual stimulation and challenges inherent in STEM as it is practiced in a highly productive and creative environment. Successes of the workshops are closely related to students' ability to connect and interact effectively with each other. This will guide students in reinforcing their commitment to success in STEM careers. In addition, the value of seeking the most up-to-date information will solidify understanding between science/special education teachers and professors to encourage diversity within their classrooms. Some of the experimental setups will be distributed to participants' middle schools for their science curricula. Teachers are strongly encouraged to integrate these demonstrations into classroom experiences in their middle schools, which will benefit even more students. The schedule of the summer and academic year civil engineering workshop activities are summarized in Tables 1 and 2.

TABLE I

CIVIL ENGINEERING SUMMER WORKSHOP SCHEDULE.

Day 2: Civil Structures Workshop	
Part 1	Civil engineering materials and applications Introduction to concrete mix design and demonstration mix with slump tests and cylinder preparation.
Part 2	Laboratory- concrete experiments: mix and curing of cylinders
Day 5: Civil Structures Workshop	
Part 1	Testing of concrete cylinders after 3 day cure.

CURRICULUM DESCRIPTIONS AND IMPLEMENTATION

Civil Engineering structures encompass a wide range of applications and materials, including buildings, bridges and portions of the space station. In a majority of cases, materials are traditional and familiar like carbon steel, concrete, aluminum, timber and masonry. In fact, civil engineers touch the lives of the public every day, from the roads used for basic transportation, to schools and office buildings and the clean tap water employed for drinking and cooking. Students easily relate to civil engineering applications and materials because of their own experiences and day to day contact with the infrastructure.

TABLE II

SATURDAY ACADEMIC YEAR CIVIL ENGINEERING WORKSHOPS.

November: Civil Structures Workshop	
Part 1	Review concrete characteristics and discuss mix proportioning.
Part 2	Examine the three, seven, twenty eight and ninety nine day cure strength data of the demonstration mix.
Part 3	Introduce truss, beam and bridge building
April: Civil Structures Workshop	
Part 1	Review basic bridge types and complete Balsa wood bridge design
Part 2	Test Balsa wood bridges.
May: Poster Presentation	
Inviting parents and guests to celebrate accomplishments	

The civil engineering portion of the workshop consisted of four primary components, including; a) lecture, b) introduction to laboratory equipment and safety, c) concrete mixing and testing and d) concept of bridge construction and testing. Primary goals include the familiarization of students and teachers to civil engineering materials and applications, introduction to concrete mix design and parameters that affect the basic performance of the material, mixing and evaluation of concrete with time as well as team functioning and individual interaction. Six teams, each consisting of 2 SLD students, 2 traditional students, 1 college student and 1 special education/science teacher were assigned a target concrete mix to design, batch, produce cylinders and test during the course of the program. By testing over time, students observe the role of age or extent of hydration on concrete strength. Group to group strength comparisons illustrate the role of mix proportions and specifically water/cement ratio and the role of admixtures on compressive strength

The summer workshop for civil structures was held on days two and five. The lecture component introduced students to civil engineering and presented examples of structural concrete, characteristics of concrete materials, constituents including Portland cement, aggregates, water, air and admixtures, design of concrete mixes, and associated laboratory equipment. The laboratory experience includes safety instructions, preparation of concrete mixes and curing of cylinders. Table 3 summarizes the important concrete trial mix parameters for the six teams. During the course of the week, each team tested and broke duplicate cylinders after three days of curing. Data were recorded. After the testing of the cylinders, each group was assigned another mix used to batch twelve test cylinders to be used for testing over a 90 day time period. Each group was assigned specific concrete mix parameters (Table 4). The concrete cylinders were left to cure and test during the academic year Saturday workshop.

TABLE 3
CONCRETE TRIAL MIX PARAMETERS FOR 3"X6" CYLINDERS

Team	Cement (lbs)	Aggregate (lbs)	Sand (lbs)	Water (lbs)	Admixtures (mls) Red./ Super
A	1.0	3.9	2.0	0.6	1.5/0.0
B	1.1	3.9	1.9	0.6	1.6/0.0
C	1.2	3.9	1.8	0.5	1.7/1.4
D	2.2	0	3.5	1.0	3.9/0.0
E	1.5	5.2	0	0.7	2.2/0.0
F	1.0	3.9	2.0	0.6	1.2/0.0

TABLE 4
LARGE BATCH CONCRETE MIX PARAMETERS FOR EACH TEAM

Team	Cement (lbs)	Aggregate (lbs)	Sand (lbs)	Water (lbs)	Admixtures (mls) Red./ Super
A	10.2	39.7	19.4	5.7	15.1/0.0
B	11.1	39.7	19.4	5.6	16.4/8.2
C	12.0	39.9	18.5	5.5	17.8/14.2
D	22.2	0.0	35.4	10.4	0.0/39.4
E	14.8	53.1	0.0	6.6	21.9/0.0
F	10.2	39.7	19.4	5.7	15.1/0.0

During the November Saturday academic year workshop duplicate cylinders were tested. Data from 28 and 99 days of curing were obtained. The students were able to crush their test cylinders and observe that concrete gets stronger the longer it is cured. They also tested two concrete beams. These beams were crushed till failure. One beam had rebar and the other did not. The students were able to see how reinforcing steel affects the strength and failure of concrete. While testing this, the students learned how to measure deflection of the beam under load. The students were then given the task of designing a miniature balsa wood bridge which they will build and test during the April academic year workshop. Each group will be given 10 pieces of balsa wood, measuring ¼ x ¼ x 36 in and a model adhesive. Teams will have to coordinate the design and construction of a balsa wood to a set of specifications. Specifically, each bridge will be required to span a distance of 8 in, be capable of passing a 2 in wide object across the roadway and be no more than 4 in height. These tasks will require working as a group, with the teacher and college students acting as engineering consultants. Bridges will be tested to failure and judged based upon the efficiency of the structure. Efficiency will account for the strength or test load to failure and the weight of the bridge.

DISCUSSIONS

Monitoring and assessment were carried out on a continual basis throughout the project. Evaluations were both qualitative and quantitative. In evaluating the success of this program, the following specific areas were measured:

1) Quality of the training students and teachers received.
2) Relationship of training to STEM career goals.
3) Interaction and attitudes amongst peers.
4) Quality and effectiveness of each summer and Saturday academic year workshops.

In order to address the quality and effectiveness of the Saturday and summer workshops, all student participants completed pre- and post test assessments of their knowledge in the content areas covered by the workshops, of their attitudes toward careers in STEM, and of their perceived self-confidence and self-efficacy in STEM areas. At the conclusion of each workshop project reaction measures were collected. This involved each student and teacher participant rating the usefulness of specific activities and materials provided and providing a narrative describing the strengths and weaknesses of the activity. In addition, each teacher assessed on their knowledge and attitudes, and also were asked to rate the knowledge and attitudes of the SLD and typical middle school students.

From the attitudes surveys, the responses from the typical and SLD students were somewhat similar. In addition, the SLD students also tended to be a little more negative than the typical students. This was to be expected as the SLD students were less engaged and they did not always totally understand the attitude survey questions. The responses from the teachers and mentors were very positive. On the 5 point scale, with a 5 being the most positive response, the means were consistently above 4.00 and many were above 4.50. Thus, responses from the teachers and mentors were very positive. The responses from the typical students were also very positive. Again, they were consistently above 4.00. Most of the SLD student responses were also positive, above 3.00, with most of the responses being above 4.00. The means and standard deviations for the parental survey results are summarized in Table 5. Inspection of Table 5 reveals that the parents' responses were very positive. All responses were above the 4.00 (Agree) rating. Based on a one-sample t-test, all the means except for efficacy were significantly above a 4.00 rating. The efficacy rating was not significantly different from a 4.00 population value. For surveys such as this, that is a very positive response.

Qualitative data and observations suggested that an area that needs to be worked on in the future is encouraging interaction between the typical students and their SLD peers. One change that we made during the Saturday academic year workshop was rotating students through teams to encourage greater interaction. Some of the SLD students had communication problems that interfered with interactions. In addition, the SLD students had a wide range of limitations, which limited the use of any one solution to the problem of encouraging interactions. Overall, most of the SLD students were very high functioning, so it was important to not single them out as these students were trying hard to mainstream. In order to keep the attention of all the students in focus, especially the SLD students, the authors plan to limit the lecture portion of the workshop to fifteen to twenty minutes. Overall, the workshop was well received by teachers, mentors, parents and both the SLD and typical student groups.

TABLE 5
PARENT SURVEY RESULTS FOR SUMMER WORKSHOP.

Variable	Mean	Standard Deviation	Sample Size (N)
Child Satisfaction	4.70	.47	23
Child Learning	4.48	.51	23
Child Interest	4.48	.67	23
Child Efficacy	4.09	.79	23
Child Team	4.39	.58	23
Parent Satisfaction	4.72	.42	23

CONCLUSIONS

The results of this study should be interpreted with caution due to small sample size and unique nature of the sample. There were 9 to 11 responses to the surveys distributed to the mentors and teachers. For the typical students there were 13 responses and for the SLD students there were 11 responses. Based on our students' surveys and observations, the students both learned from and enjoyed the summer and Saturday academic year workshops. Although all the workshops received high ratings, the highest rated summer workshop was consistently the civil engineering concrete activities, probably due to all the hands-on projects and the students got the experience of using the university experimental laboratory facilities.

Based on students, mentors, teachers and parents surveys the following conclusions can be drawn:

1) Both SLD and typical students were satisfied with the summer and Saturday academic year workshops.
2) The workshops have increased the SLD students' confidence in their ability to do well in the STEM subject matter.
3) From the attitude surveys, both SLD and typical students' responses indicate that they enjoyed and learned a lot from the workshops. Also, they enjoyed working with a team on real world projects.
4) From the teachers and mentors surveys, mainstreaming does lead to a greater appreciation of diversity in learning styles among SLD and typical middle school students, college students, and science/special education teachers.
5) The hands-on activities increase self confidence, self efficacy and career interest in STEM areas among SLD and typical students.

Since the program is funded for three years, the authors will collect more data to replicate the significance of this study with larger and broader sample. Longitudinal evaluation of participants' interests in STEM curricula as they graduate from high school and enter into college will be investigated statistically. The program can be replicated by other universities that assure STEM based education to support the development of academic progress and career interest of students with SLD. Our long range goals are to develop a middle/high school-to-college vertically integrated transition program and an undergraduate retention program for SLD students seeking degrees in STEM.

ACKNOWLEDGMENT

The material is based upon work supported by the National Science Foundation under Grant No. 0622767. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation (NSF).

We would like to thank The University of Akron College of Engineering, the Ohio Space Grant Consortium, as well as the Summit and Stark County school systems in support of this project.

REFERENCES

[1] Changing America: the new face of science and engineering," final report, The Task Force on Women, Minorities, and the Handicapped in Science and Technology, Washington D. C., 1989.

[2] Lent, R. W., Brown, S. D., & Hackett, G., "Toward a Unifying Social Cognitive Theory of Career and Academic Interest, Choice, and Performance," *Journal of Vocational Behavior,* 45, 79-122, 1994.

[3] Mastropieri, M. A. & Scruggs, T. E., Lent, R. W., Brown, S. D., & Hackett, G. "Science for Students with Disabilities," *Review of Educational Research*, Vol. 62, No. 4, pp. 377-411, winter 1992.

[4] Lam, P. C., Srivatsan, T. S., Doverspike, D., Mawasha, P., and Vesalo, J., "A Ten Year Assessment of the Pre-Engineering Program for Under-represented, Low income and/or First Generation College Students At The University of Akron," *Journal of SMET Education: Innovation and Research*, 2005.

[5] Mawasha, P., Lam, P. C., Veslo, J., Leitch, R., and Rice, S., "Girls Entering Technology, Science, Math and Research Training (GET SMART): A Model for Preparing Girls in Science and Engineering Disciplines," *Journal of Women & Minorities in Science & Engineering,* Begell House, Inc., Vol 7, No. 1, March 2001.

[6] Mastropieri, M. A., Scruggs, T. E., Lent and Magnusen, M. "Activities-Oriented Science Instruction for Students with Disabilities," *Learning Disability Quartery*, Vol. 22, No. 4, pp. 240-249, autumn, 1999.