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An Evaluation of a STEM Program for Middle School Students on Learning Disability Related IEPs

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Abstract

A year long Science, Technology, Engineering and Math (STEM) program was developed for middle schools students on Individualized Education Programs (IEPs) involving learning disabilities. The workshops were designed to encourage students both on IEPs and not on IEPs to explore STEM as a future career choice by building their knowledge and confidence. The participants in the workshops included 11 students on IEPs and 15 students not on IEPs. Parents also provided feedback regarding their attitudes toward the program. The results indicated that there were increases in student participant knowledge and career interest for both the students not on IEPs and the students on IEPs. Overall, reactions to the program from both students and parents were quite positive.

Introduction

Producing a sufficient pool of qualified graduates in the areas of science, technology, engineering and math (the STEM occupations) has long been a challenge for American Universities and Colleges. The supply problem in the STEM areas is likely to get worse in the near future, as the number of students pursuing degrees appears to be shrinking. One solution to alleviating the potential shortages is to increase the number of students from underrepresented areas considering majoring in and pursuing careers in STEM (National Science Foundation, 2000).

One traditionally underrepresented group that has increased in size is students with disabilities, including those students with learning disabilities (AccessSTEM, 2007; Grumbine & Alden, 2006; National Council on Disability and Social Security Administration, 2000; National Science Foundation; 2000). Students with learning disabilities have average to above average intelligence but have difficulties acquiring information and expressing their knowledge (IDEA, 1975; NJCLD, 1998) This may be reflected in speech, language, listening, speaking, writing, reasoning, or performing mathematical operations. Operationally, students with learning disabilities can be considered as that subset of individuals in the educational system who have an Individualized Education Plan (IEP) that is based on a diagnosis consistent with an impairment in processes related to learning.

The purpose of the current study was to evaluate a year-long academic program designed to build interest in STEM careers among middle school children on learning disability related IEPs. In order to do this, a summer and Saturday workshops were developed based on principles of activity based learning and universal education. The goal of the program was to increase middle school students' knowledge of STEM careers and increase their self-confidence in academic areas.

Defining Students with Learning Disabilities

As indicated above, students with learning disabilities have a disorder in basic psychological processes that impact the acquisition and expression of information. In designing the academic workshops, it was our intent that the programs be aimed at those middle school students with specific learning disabilities. Operationally, we defined the potential students as being those students on an IEP as a result of a specific learning disability. We relied upon the schools to identify and recommend students. This requirement appeared to be interpreted liberally and some of the students reported that their IEP was also based on emotional or physical disabilities. The issues involved in obtaining accurate information on a specific diagnosis do not appear to be limited to this study, but appear to be common as other conditions may co-occur with learning disorders (Grumbine & Alden, 2006; Pastor & Reuben, 2005; Shaw, Cullen, McGuire, & Brinckerhoff, 1995). For that reason, in reporting the results we believe it is more accurate to describe the one group of students as being on an IEP, or on a learning disability related IEP.

A second group of students was also included in the workshop. This second group included students interested in STEM occupations but not on an IEP. This group was included not for purposes of serving as a control group, but rather based on the idea that this would allow for a more natural educational environment, contribute to the concept of group work, and also allow for a greater appreciation of diversity in all students and personnel involved in the program. During the program, no differentiation was made between those students on IEPs and those students not on IEPs, other than that the students on IEPs had been recruited from the schools specifically because they met this mandated requirement.

Increasing Career Interest

In order to reduce labor shortages in the STEM occupations and to increase diversity in terms of backgrounds, we felt it was necessary to start early. For that reason, we decided to target middle school children, with the intent of developing a high school level program for further follow up at a later point in time.

Social cognitive theories (Lent, Brown, &

Hackett, 1994, 2000) recognize that early learning experiences are critical in the development of career interests, motivation, and choices. 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. Thus, based on social cognitive career theories, we would expect that positive educational and learning experiences would shape self confidence and career aspirations among students, including those on learning related IEPs.

According to a comprehensive literature review of 66 reports involving science education for students with disabilities (Mastropieri & Scruggs, 1992), knowledge and learning are facilitated through providing activities-oriented science curricula. Thus, we propose that the use of hands-on educational activities would lead to better learning for students on IEPs. In addition to better learning, such activities should lead to increased self confidence and career motivation.

Design of the Workshop

Based on the review of the literature (AccessSTEM, 2007; Gosselin & Macklem-Hurst, 2002; Mastropieri & Scruggs, 1992; Norman, 1997), it appeared that the best approach to building interest and self confidence was one that relied upon inclusive, inquiry-based science, emphasized problem-based learning, and incorporated visual demonstration. Group work and active learning based teaching have been proposed as effective practices for use with students and teachers in general, as well as students with disabilities (Access STEM, 2007; Gosselin, & Macklem-Hurst, 2002; Norman, 1997).

In addition, given the diversity of the students in the program, we also incorporated principles from universal design in education (Access STEM, 2007; Dolan & Hall, 2001; Grumbine & Alden, 2006). The universal design of training or educational programs involves developing programs that are usable by all people, to the greatest extent possible, without the need for adaptation or specialized design (Burgstahler, 2006a, 2006b; Dolan & Hall, 2001). In creating course content, this involves paying attention to principles such as: 1) provide multiple media for the presentation of material and deliver material clearly and in multiple ways; 2) motivate all students; 3) design training to accommodate diverse learning styles; 3) use large, tactile aides; 4) provide cognitive and memory support including emphasis of major points and outlines; 5) make training practical, relevant, and hands-on; 6) facilitate interaction through group work; and 7) allow for peer interaction and feedback (Burgstahler, 2006a, 2006b).

In order to develop the program, the course developers relied upon previous experiences with programs designed for ethnic minorities (Lam, Mawasha, Doverspike, McClain, & Vesalo, 2000; Lam, Srivatsan, Mawasha, Vesalo, & Doverspike, 2005). Three areas were identified for the development of workshops. The areas were: 1) simple and complex machines, as incorporated into the "A World in Motion," program (SAE International, 1990); 2) smart balloons, including sensors and information technologies (Zhe, Zhao, & Lam, 2006); 3) civil structures, which was principally concrete preparation and testing.

Based on these three content areas, we developed workshop material suitable for sixth to eighth graders. The workshops were designed so that students on IEPs and those not on IEPS worked together in various hands-on activities. The program gave the participants opportunity for direct observation and participation in on-going research activities. The groups were formed so that they contained two students on IEPs, two students not on IEPs, one college student mentor, and one science/special education teacher.

Each group had their own table in a large classroom. The classroom was set up and dedicated to the STEM program. A second classroom was available for meetings, snacks, and activities. A separate laboratory-classroom was used for the concrete mixing and testing. Some of the activities involving team building or the balloon launch were carried out on an athletic field next to the classroom building.

The workshops consisted of a week of one day, 8:30 AM to 3:15 PM, summer classes and also seven, one day Saturday workshops during the academic year. The Saturday workshops reinforced the knowledge which the students learned during the summer workshops. At the end of the Saturday academic year workshops, students presented their learning during the poster session that was held to celebrate the students' accomplishments. Table 1 summarizes the topics and course content covered by the summer and Saturday workshops.

Evaluation of the Academic Program

The overall objective of this paper is to describe and evaluate a summer and academic

Month	Day	Topic Area	Course Content
Summer	Monday	Machines	A World in Motion. Simple machines. Can crusher competition. Levers. Building simple and complex machines.
Summer	Tuesday Friday	Civil Structure	Civil engineering materials and applications. Introduction to concrete mix design and demonstration mix with slump tests and cylinder preparation. Laboratory- concrete experiments: mix and curing of cylinders
Summer	Wednesday Thursday	Smart balloon	Basic concepts of flight aerodynamics. Environmental monitoring and space surveillance. Build and test a 3 ft smart balloon. Candle pump and thermal pump experiments. Wireless communication systems used in the smart balloon.
September	Saturday	Smart balloon	Assemble and launch a 6-foot helium balloon with a temperature sensor and a pressure sensor.
October	Saturday	Machines	Toy Manufacturing design competition. Discussion of team building, time management, mass production, quality control and conflict management.
November	Saturday	Civil Structure	Review the concrete characteristics and discuss mix proportioning. Examine the strength data. Bridge building.
January	Saturday	Smart Balloon & Machines	Analyze pressure and temperature data. Build and test a remote-controllable tow truck.
February	Saturday	Smart Balloon	Computer-based experiments using microcontrollers. Robot competition using Lego Mindstorm.
April	Saturday	Civil Structure	Bridge building.
May	Saturday	Poster	Poster presentation of results. Wrap up of program.

Table 1. Program Content Outline

year program intended to stimulate and encourage a greater interest in STEM among middle school students, including those students on IEPs. Through primarily hands-on activities, the intent was to build the technical self-confidence crucially needed to succeed in STEM high school and college programs, with the eventual intent of increasing the number of students on learning related IEPs considering STEM majors in college and careers in STEM areas.

A secondary objective was to expose science and special education teachers to working with a diverse mix of students using hands-on activities. The feeling was that this would provide teachers with positive attitudes toward working with students on IEPs and also transfer back to the classroom. This objective was not specifically addressed in this study, as our purpose was to concentrate on the reactions of the students.

The main hypothesis to be tested by this study is that providing intensive summer and Saturday academic year workshop experiences involving hands-on exercises will lead to increased self-confidence and career interest in the areas of STEM among students with and without IEPs. The students not on IEPs were not included to be a control group, as we did expect to see increases in their interest and self-confidence as well. The evaluation of the program and the testing of the hypotheses were based on knowledge tests and surveys completed by the students during the course of the program. In addition, the parents completed a survey where they were asked to evaluate the changes in the interest of their children following the workshops.

Method

Participants

The participants of this program were middle school children in grades six to eight. There were two groups, the students on IEPs (N = 11) and the students not on IEPs (N = 15). Not all the students or participants were able to attend all the sessions. This reduced the number of students in any particular comparison or for any specific statistical test.

Of the 11 students on IEPs, 5 were female and 6 were male. In terms of ethnicity, 8 were White, 1 Black, 1 Asian American, and 1 unidentified. The average grade in school was 7.00 and the average GPA was a 3.01.

The parents indicated a reason for each student's IEP. The reasons for the IEP included dyslexic (1), language arts (4), math (2), speech (2), written (1), anxiety (1), hearing (1), and autistic (1). The total is more than 11 due to some parents listing multiple reasons.

Of the 15 students not on IEPs, 5 were female and 8 were male. In terms of ethnicity, 8 were White, 5 Black, and 2 Asian American. The average grade in school was 7.40 and the average GPA was a 3.64.

Knowledge Test

In order to assess changes in student knowledge, a 15-item multiple-choice test was administered before and after the summer workshop. The pretest was administered the first day of the summer workshop. The posttest was administered at the completion of the individual workshops and on the last or fifth day of the summer workshop. A sample question was:

How does using a lever make lifting an object easier?

A. It reduces the weight of the object.
B. It reduces the work.
C. It trades force for distance.
D. It requires more energy but less work.
E. I do not know the answer.

The students selected the correct answer from the 4 alternatives or the *do not know the answer* option. The internal consistency reliability was .57 for pretest score and .66 for the posttest.

Student Reaction Measure

At the end of the first year, students were asked to evaluate the program. As part of the evaluation of the program, they completed an evaluation sheet. This evaluation rating consisted of 6 items, which were responded to using a 5 point Likert scale ranging from *strongly disagree* to *strongly agree*. The six questions were:

1. I enjoyed the engineering program for students.
2. I learned a lot in this program.
3. I would like to take more workshops or school classes like these.
4. I think I could do well in a high school class on subjects similar to those in this program and workshops.
5. I enjoyed working with a team on real world projects.
6. One of the advantages of working with other people on a project is that you get to know more about how other people think.

Career Interest Survey

A career interest survey was developed and administered before and after the program. The before measure was taken the first day of the summer workshop during the first hour. The after measure was taken after the final Saturday workshop. There were nine questions or items. Each item was responded to using a 5 point Likert scale ranging from *strongly disagree* to *strongly agree*. The nine questions were:

1. It is clear to me what a career in Engineering would be like. I know what an Engineer does.
2. I would like to major in Engineering in College.
3. If I went to College in Engineering, I believe I would do well in my courses.
4. I would like to be an Engineer.
5. It is clear to me what a career in Science would be like. I know what a Scientist does.
6. I would like to major in some area of Science in College.
7. If I majored in science in College, I believe I would do well in my courses.
8. I would like to take a lot of Science classes in High School.
9. I would like to be a Scientist.

Parent Ratings

At the conclusion of the first year, surveys were distributed to the parents during the final Saturday session. For purposes of anonymity and confidentiality, the parental surveys were not identified by name and could not be tied to or linked to the student. Each item was responded to using a 5 point Likert scale ranging from *strongly disagree* to *strongly agree*. The six questions were:

1. I believe my child enjoyed this program.
2. I believe my child learned a lot in this program.
3. I believe this program has positively influenced my child's interest in taking more workshops or school classes like this one.
4. I believe this program has increased my child's confidence in their ability to do well in high school classes with similar subject matter.
5. I believe my child enjoyed working with a team on real world projects.
6. As a parent, I was satisfied with the program.

Procedure

The distribution and collection of the tests and reaction measures for the students was carried out by one of the workshop instructors. The forms were then turned over to a separate evaluation team for data entry and analysis. The instructors did not have access to the reaction or test data, only the evaluator had access to that data.

As might be expected, a factor analysis and reliability analysis suggested that the career pretest might be measuring one general factor. A single overall score was created from the nine items. The coefficient alpha for the overall score was .84.

Results

Changes in Student Knowledge

The change in knowledge scores from pretest to posttest for all students is presented in Table 2. The sample size is less than 26 because not all students were present for both the pretest and posttest.

Inspection of Table 2 indicates that the change or difference score was significant at beyond .001 based on a repeated measures t-test. The mean increase in score was 4.33 on a 15 item measure, an improvement that was quite dramatic for such a short term program.

Although a repeated measures ANOVA suggested no effect for either the student classification [F(1,19) = .174, p = .68] or the interaction of student classification and the time of testing [Wilks Lamda = .99, F(1,19) = .24, p = .63], the means are presented below for each group, or by student classification. The change in knowledge scores by student classification are shown in Table 3. Students on IEPs slightly outperformed those not on an IEP on both the pretest and the posttest.

Total Score	N	Mean	SD	t	Sig.
Pretest	21	5.39	2.46	7.54	.00**
Posttest	21	9.71	2.57		

**$p \leq .01$, indicates a significant change from pretest to posttest.

Table 2: Change in Knowledge Scores for all Students

Classification – IEP	Mean Pretest	Mean Posttest	Change	N
No	5.33	9.42	4.09	12
Yes	5.44	10.11	4.67	9

Table 3: Change in Knowledge Score by Student Classification

Student Reactions to the STEM Program

At the conclusion of the STEM program year, students completed reaction surveys. The sample size, N = 17, was less than 26, because a number of students could not attend the final Saturday workshop or had to leave before completion of the reaction measure.

The results for the reaction surveys appear in Table 4. Although the ratings overall for the students on IEPs were not as high as for the students without IEPs, the only significant difference, based on the independent groups t-tests, was for the item asking about *taking more STEM classes or workshops*, with the students not on IEPs being more positive toward taking more STEM classes and worskshops. The ratings for both classifications of students were all 4.00 or higher.

Student Career Interests

At the beginning and end of the STEM program, the students completed a survey about their career interests. The sample size, 15, was less than the total sample of 26, because some students missed the administration of one of the surveys. Only students who completed both the pre program career survey and the post program survey were included in this analysis.

The resulting means, standard deviations, and repeated measures t-tests appear in Table

Variable	IEP	N	Mean	SD	t	Sig.
Enjoyed the program	No	9	4.78	.44	1.38	.19
	Yes	8	4.38	.74		
Learned a lot	No	9	4.78	.44	1.87	.09
	Yes	8	4.25	.71		
Take more STEM classes	No	9	4.89	.33	2.16	.05*
	Yes	7	4.29	.76		
Do well in High School	No	9	4.56	.53	1.44	.17
	Yes	7	4.00	1.00		
Enjoy working with team	No	9	4.44	.53	.05	.96
	Yes	7	4.43	.79		
Get to know people	No	9	4.56	.73	1.44	.17
	Yes	8	4.00	.82		

*$p \leq .05$, indicates a significant difference between groups of students.

Table 4: Student Reaction Results

Variable	IEP	N	Pre Program		Post Program		Repeated	
		N	Mean	SD	Mean	SD	t	Sig.
Knowledge of Eng.	All	15	3.6	.74	4.4	.83	3.60	.00**
	No	9	3.67	.71	4.56	.53	3.41	.00**
	Yes	6	3.50	.84	4.17	1.17	1.58	.18
Major in Eng.	All	15	3.07	.88	3.67	1.18	2.81	.01**
	No	9	3.33	1.00	4.11	1.17	3.50	.01**
	Yes	6	2.67	.52	3.00	.89	.79	.47
Do Well in Eng.	All	15	3.73	.70	4.0	.85	1.74	.10
	No	9	4.00	.50	4.44	.73	2.53	.04*
	Yes	6	3.33	.82	3.33	.52	.00	1.00
Like to be an Eng.	All	15	3.47	.99	3.80	1.26	1.78	.10
	No	9	3.89	.93	4.22	1.20	1.41	.20
	Yes	6	2.83	.75	3.17	1.17	1.00	.36
Knowledge of Science	All	15	3.80	1.08	4.27	.70	1.45	.17
	No	9	3.67	1.22	4.33	.71	1.33	.22
	Yes	6	4.00	.89	4.17	.75	.54	.61
Major in Science	All	15	3.53	1.19	4.07	.80	2.09	.06
	No	9	3.78	1.30	4.33	.71	1.47	.18
	Yes	6	3.17	.98	3.67	.82	1.46	.20
Do Well in Science	All	15	3.93	.88	4.07	.59	1.00	.33
	No	9	4.22	.67	4.22	.67	.00	1.00
	Yes	6	3.50	1.05	3.83	.41	1.00	.36
Take Science in HS	All	15	3.87	1.06	4.13	.74	1.74	.10
	No	9	4.33	1.00	4.44	.73	1.00	.35
	Yes	6	3.17	.75	3.67	.52	1.45	.20
Like to be a Scientist	All	15	3.07	1.16	3.6	.83	1.83	.09
	No	9	3.11	1.27	3.78	.97	1.51	.17
	Yes	6	3.00	1.10	3.33	.52	1.00	.36
Overall	All	15	32.07	5.09	36.00	6.28	4.15	.00**
	No	9	34.00	4.80	38.44	6.17	3.23	.01**
	Yes	6	29.17	4.36	32.33	1.94	2.53	.05**

*$p \leq .05$; **$p < .01$, indicates a significant change for that group from pre to post survey.

Table 5: Student STEM Career Interest Survey Pre and Post Program

5 for all students responding to both surveys, for students on IEPs responding to both surveys, and for students not on IEPs. A statistical test was conducted for each group to determine if there had been a difference from the pre survey compared to the post program survey. The statistical test was a repeated measures t-test.

Inspection of Table 5 indicates that there was a significant increase in the overall score on the career measure for the total sample, for the students not on IEPs, and for the students on IEPs. The increase or difference was larger for the students not on IEPs than for the students on IEPs.

At the individual item level, most of the differences or changes in score are not significant. This is not unexpected given the lower power of this test for the sample sizes available, especially for the students on IEPs classification. The increases that were significant for the total sample were for Knowledge of Engineering and Major in Engineering. The increases that were significant for the students not on IEPs were for Knowledge of Engineering, Major in Engineering, and expectation that they would Do Well in Engineering in College; in all cases their responses were more positive after the workshops and year long program.

Parent Reactions

At the conclusion of the summer workshop, surveys were sent out to all the students' parents. These surveys were sent to their homes and then returned. The surveys were anonymous; there was no linking of the parents to students or identification of parents.

The means and standard deviations for the parental survey results are summarized in Table 6. Inspection of Table 6 reveals that the parents' responses were very positive.

Discussions and Conclusion

Based on our students' surveys and observations, the students both learned from and enjoyed the summer workshop. From the reaction surveys, the responses from the students on IEPs and not on IEPs were both positive, although the students not on IEPs were more positive overall and on the question dealing with taking more STEM courses in the future. This might be expected in that the students on IEPs did not always appear as engaged in the workshops and in some cases had difficulty understanding the attitude survey questions. In particular, comments from the students suggested that the students on IEPs wanted less time spent on lectures and more activities to fill free time.

Variable	N	Mean	SD
Child Enjoyed Program	18	4.56	.51
Child Learned a Lot	18	4.44	.62
Increased Child's Interest	18	4.17	.86
Increased Child's Confidence	18	4.28	.67
Child Enjoyed Teams	18	4.22	.94
Parent Satisfied	18	4.77	.46

Table 6: Parent Reaction Survey for Summer Workshop

Comments from students, parents and teachers suggested that an area that needs to be worked on in the future is encouraging interaction between the students on IEPs and the students not on IEPs. One change that we made during the Saturday academic year workshop was rotating students through teams to encourage greater interaction. Some of the students on IEPs had communication problems that interfered with interactions. In addition, the students on IEPs had a wider range of limitations than originally expected, which limited the use of any one solution to the problem of encouraging interactions.

One of the main purposes of the survey was to increase knowledge and interest in STEM careers, as well as increasing self-confidence. Changes in these areas were assessed using a career survey completed before and after the program. Overall, the program was successful in achieving changes in perceptions and knowledge among the total sample, for the students not on IEPs, and for the students on IEPs. The parental response to the program was also quite positive.

The increase or difference was larger for the students not on IEPs than for the students on IEPs. While at the individual item level, most of the differences or changes in score were not significant, this was partially a function of the small sample size. The engineering items did seem to reflect more of a positive change than did the general science items, which is consistent with the heavy engineering focus of the workshops. In the future, we plan to add more science and math content to the workshops.

A major limitation was the small sample size. This limited the power of any significance tests. However, given the cost of the program, there is a limit to how many students can be placed through the workshops.

A second limitation was the lack of a control group. Students not on IEPs were included, but it was expected that there would be positive changes for this group as well as for the IEP students. At present, it would not be realistic to add a control group for the students on IEPs.

A third limitation was the lack of objective measures. Our intent is to increase interest in STEM careers. This is a long term goal and we do expect to continue to follow up with students in order to determine their continued interest in STEM careers.

In conclusion, overall the workshops did lead to positive increases in knowledge and attitudes toward STEM careers for students on IEPs and those not on IEPs. The parental reaction was also quite favorable. Overall, the student participants were very satisfied with the summer and academic year workshops. Based on comments received from the participants, suggested improvements for future workshop include: 1) shorter lecture times and lunch times; 2) more hands-on activities; and 3) rotating students through teams to encourage greater interaction.

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