AC 2012-2946: THE IMPACT OF A PROBLEM-BASED LEARNING LAUNCHER UNIT ON EIGHTH GRADE STUDENTS' MOTIVATION AND INTEREST IN SCIENCE

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The Impact of a Problem-Based Learning Launcher Unit on Eighth Grade Students' Motivation and Interest in Science

Science Learning: Integrating Design, Engineering, and Research (SLIDER) is a five year NSF-funded research project that involves collaboration between K-12 educators, university faculty, and educational outreach specialists. The project's objective is to design and implement a Problem-based Learning (PBL) curriculum using engineering design and LEGO robotics as the context for teaching eighth grade physical science content and process skills while encouraging critical thinking. In addition to studying the curriculum's impact on student learning, we are also examining its impact on student motivation and interest in science. In this second year of our project, participating teachers at one of our school sites implemented a 4-week Launcher Unit that focused on engaging students in scientific inquiry and engineering design. Our purpose is to examine ways in which student motivation and interest in science were affected by engaging with the SLIDER PBL curriculum.

Theoretical Framework

In her review of problem-based learning, Hmelo-Silver (2004) defined PBL as a form of experiential learning in which students work in collaboration with others to investigate a meaningful problem. Problems are typically ill-defined and require students to consider multiple solutions (Barrows, 2002; Savery, 2006). According to Duch, Groh, and Allen (2001), engaging in PBL methods help students develop skill in critical thinking, evaluation, cooperative and collaborative learning, and communication. Savery (2006) identifies several best practices in PBL, including (1) making students responsible for their own learning, (2) using ill-defined problems that allow for free inquiry, (3) integrating learning across disciplines, (4) requiring collaboration, (5) requiring that what is learned is "applied back to the problem with reanalysis and resolution" (p. 13), and (6) using authentic problems that are valued in the real world.

The SLIDER curriculum was designed with PBL best practices in mind. Challenges begin with an authentic, ill-defined problem that requires students to work collaboratively toward a solution. As students move through the challenge, they work in groups to iteratively design and improve their solutions. For many of these challenges, students must design experiments and/or conduct investigations, collecting data that is relevant for meeting the challenge. Results from student investigations are used to improve solutions, and throughout the curriculum, students are expected to engage in the activities of engineers, scientists, designers, and architects.

As Wirkala and Kuhn (2011) explain, most research on PBL has focused on adult students in medical schools, and results have not been conclusive regarding PBL's effectiveness. In K-12 and post-secondary settings, implementation papers are more common than reports that empirically demonstrate PBL's effectiveness. However, in the limited number of published studies conducted at the middle school level, PBL has been shown to increase achievement in comprehension of instructional concepts (Wirkala & Kuhn), science achievement (Liu, Hsieh, Cho, & Schallert, 2006), science self-efficacy (Liu et al. , 2006), and transfer of problem-solving skills (Pedersen & Liu, 2003). Kolodner et al. (2003) also describe results from studies on *Learning by Design*™ (LBD)—a PBL approach to teaching middle school science—which indicated that students who received instruction in LBD outperformed control groups in acquisition of science knowledge and science process skills. LBD students also had better collaborative and metacognitive skills than did their non-LBD counterparts. Positive effects on student motivation have also been found with high school students. Sungur and Tekkaya (2006), for example, found that students receiving PBL instruction in science had greater critical thinking skill, motivation, and self-regulation than did students in a control group.

Using LEGO robotics to support PBL has been suggested by a number of researchers. Carbonaro, Rex, and Chambers (2004), for example, conducted a pilot study in two middle schools to investigate students' problem-solving approaches when using LEGO robotics in a PBL environment. The authors concluded that building autonomous robots provided a highly student centered-learning environment that supported students' creativity and problem-solving ability. In their study of a middle school LEGO robotics summer camp, Williams, Ma, Prejean, and Ford (2008) found that participants' physics content knowledge increased over the course of the camp, though there were no significant increases in their scientific inquiry skills. Barker and Ansorge's (2007) study of an afterschool LEGO robotics program for students ages 9-11 revealed that participants' knowledge of computer programming, robotics, mathematics, and engineering concepts increased due to program participation. In each of these studies, use of LEGO robotics happened either outside the regular school day and/or outside the context of a science class. We were unable to find published research about using LEGO robotics to support science learning in a middle school science course.

Research Design and Methods

In this study, our purpose was to examine the effectiveness of one SLIDER unit on students' attitudes, motivation, and self-efficacy in science. To determine whether attitude, motivation, and self-efficacy differed when students were engaged in PBL instruction and when they were receiving traditional instruction, we used a single-subject experimental design in which all participating students (n=350) completed questionnaires (Likert and open-ended items) during the third week of the curriculum intervention and then again 10 weeks after the completion of the intervention. The questionnaires measured students' (1) attitude toward science in society, (2) attitude toward science class, (3) interest in science related jobs, (4) interest in science related activities, and (5) science self-efficacy.

These instruments were created using two existing scales: the *Is Science Me* (ISME) scale (Aschbacher, Li, & Roth, 2010; Gilmartin, Li, & Aschbacher, 2006) and the *Modified Attitudes toward Science Inventory* (MATSi) developed by Weinburgh and Steele (2000). From the ISME, we used items on interest in science activities outside of school, interest in science related jobs and activities, and science self-efficacy. From the MATSi, we used items on attitude toward science in society and attitude toward science class.

The original instruments had been pilot tested, and authors provided information on both validity and reliability of their instruments. However, because we combined instruments and dropped some items, we pilot-tested our new instruments during the previous school year with 611 eighth grade students in order to determine validity via confirmatory factor analysis. We used principal components factor analysis with varimax rotation techniques and omitted items with factor loadings below .50. The final instrument contained 55 Likert items measuring 5 constructs.

Reliability was high, with internal consistency measures (Cronbach's α) ranging from .80 to .92 for each construct.

SLIDER Curriculum. The 4-week PBL curriculum was implemented in one school with three eighth-grade physical science teachers. Two teachers implemented the curriculum in each of their 5 class periods, and one teacher implemented the curriculum in 1 period; thus there were 11 individual classes, across 3 teachers, in which the curriculum was implemented. Participating teachers were in their second year of the project and had received approximately 40 hours of training in the summer of 2010 on PBL. During the 2010-2011 academic year, teachers implemented several PBL instructional units and received additional professional development. In the summer of 2011, teachers returned for an additional 40 hours of training on PBL and the SLIDER curriculum. In the second week of the 2011-2012 academic year, teachers implemented the SLIDER Launcher Unit.

During the 4-week PBL intervention, teachers used a Launcher curriculum to introduce students to PBL/SLIDER practices as well as to increase their scientific inquiry skills. **Learning Set 1: Accident Challenge** focused on science process skills, and **Learning Set 2: Nuclear Reactor Challenge** introduced building and programming skills needed to use LEGO NXT kits. In the first Learning Set, students conducted investigations of a car accident site using LEGO cars and ramps as models (see Figure 1). Students were provided with an ill-defined problem (how to determine whether speed was a factor in car accidents that kept occurring at a certain intersection) and was provided this challenge:

> *The mayor...has challenged local engineering companies, including yours, to develop a solution...to determine whether Vehicle A was speeding during these collisions. The police investigate the accidents immediately after they occur, and the chief of police has stated that they must have evidence from the crash site to confirm the driver was speeding. Your company thinks it can provide a solution.*

Figure 1. Accident Challenge

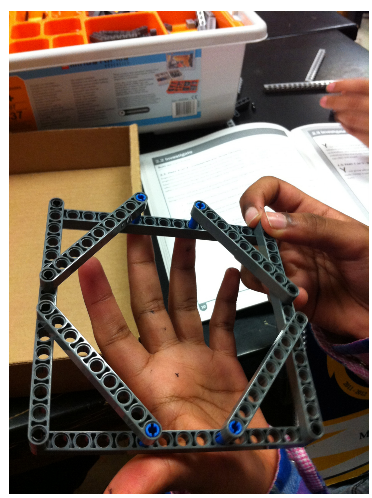

Figure 2. Rigid Structures

Throughout the learning set, students identified criteria and constraints of the challenge, designed procedures, investigated the problem, communicated findings, reflected on work, and iterated/ redesigned procedures. Students worked in small groups (3-4 students) and were required to record procedures and data, demonstrate solutions, and to share results with the entire class.

In the second Learning Set, students were challenged to create rigid structures using various LEGO parts (see Figure 2). Due to the timing of benchmark testing, students were not able to complete the programming activities in Learning Set 2, but they did complete the rigid structure activity, which required them to investigate various cart body designs, evaluate strengths and weaknesses, and create rigid structures given certain constraints.

During the traditional instruction term, teachers covered content in chemistry using the course textbook. Instructional activities involved teacher lecture, student note-taking, students completing worksheets and lab activities, and students completing quizzes and tests that were mostly multiple-choice.

Participants. Eighth grade students in one school participated in this study. Although there were approximately 350 students in the target population, the sample for the study is much smaller. Issues related to student attrition, obtaining parental consent, and missing data from one survey for one teacher reduced the actual sample size to 136 for part one of the survey and 84 for the second part.

The school where the study took place is a Title I school that did not make Annual Yearly Progress in the 2010-2011 academic year. Approximately 93% of 8^{th} grade students met or exceeded standards in reading and in English/language arts, 86% met or exceeded standards in math, and 79% met or exceeded standards in science and in social studies. Just over 56% of students are economically disadvantaged, 10% have an identified disability, and 9% are English language learners. Forty-nine percent of the students are African-American, 29% are Caucasian, 18% are Hispanic, and 4% are Asian.

Results

Comparisons were made in each of the five areas examined: (1) students' attitude toward science in society, (2) students' attitude toward science class, (3) students' interest in science related job activities, (4) students' interest in science activities outside of school, and (5) science self-efficacy. We used matched-pair t-tests to examine differences between students' attitudes, interests, and self-efficacy when they were instructed using the PBL curriculum and when they were being taught via the traditional curriculum. Because we did not wish to inflate error rate, we divided our experiment-wise error rate of .10 by the number of comparisons (5) and set α at .02 for each comparison.

As illustrated in Table 1, there were significant differences in students' attitude toward science class ($t_{135} = 2.408$, $p < .017$) and students' science self-efficacy ($t_{83} = 5.160$, $p < .000$). Students' attitude toward science class was higher during the SLIDER instruction than during the traditional instruction, and students' science self-efficacy was higher during the SLIDER instruction than during the traditional instruction.

Table 1. Comparisons of Attitude, Interest, and Self-Efficacy in Science

	Mean	N	SD	diff	t	df	Sig	SES†
Attitude								
Science in Society$_{PBL}$	3.0987	136	.38133	.02693	.767	135	.444	.07
Science in Society$_{Trad}$	3.0718	136	.44690					
Science Class$_{PBL}$	2.9321	136	.56800	.09312	2.408	135	.017*	.16
Science Class$_{Trad}$	2.8390	136	.57077					
Interest								
Science Related Jobs$_{PBL}$	2.6950	136	.65284	.09321	1.657	135	.100	.14
Science Related Jobs$_{Trad}$	2.6018	136	.67513					
Science Related Activities$_{PBL}$	2.3837	83	.68627	.01975	.238	82	.813	.03
Science Related Activities$_{Trad}$	2.3640	83	.70771					
Self-Efficacy								
Science Self-Efficacy$_{PBL}$	3.4828	84	.52842	.34736	5.160	83	.000*	.66
Science Self-Efficacy$_{Trad}$	3.1354	84	.62761					

*Difference is statistically significant at the .02 level.
†Standardized effect size, calculated by dividing the mean difference by PBL standard deviation.

Differences in attitude toward science class, though statistically significant, had a small effect size, indicating a .16 standard deviation difference between attitude toward science class during the SLIDER and traditional curricula. To further evaluate differences in this area, we compared differences for each item in the *attitude toward science class* part of the instrument (see Table 2).

Table 2. Comparisons of Attitude toward Science Class, by Item

		Mean	N	SD	diff	t	df	Sig	SES
I like science class.	PBL	3.10	133	.843	.158	2.315	132	.022	.19
	Trad	2.94		.868					
I would like to do some extra reading in science.	PBL	2.15	134	.880	-.164	-2.145	133	.034	-.19
	Trad	2.31		.844					
I like the challenge of science assignments.	PBL	2.85	135	.824	.000	.000	134	1.00	--
	Trad	2.85		.824					
Science is one of my favorite subjects.	PBL	2.73	131	1.02	-.008	-.099	130	.921	-.007
	Trad	2.74		.957					
I have a real desire to learn science.	PBL	2.80	133	.925	.180	2.326	132	.022	.19
	Trad	2.62		.867					
When I hear the word *science* I have a feeling of dislike. †	PBL	3.10	127	.907	.276	3.304	126	.001*	.30
	Trad	2.83		.892					
I feel tense when someone talks to me about science. †	PBL	2.90	134	.865	.000	.000	133	1.00	--
	Trad	2.90		.839					
It makes me nervous to even think about doing science. †	PBL	3.25	132	.765	.129	1.797	131	.075	.17
	Trad	3.12		.801					
It scares me to have to take a science class. †	PBL	3.39	135	.722	.178	2.419	134	.017	.24
	Trad	3.21		.764					
I have a good feeling toward science.	PBL	3.07	132	.754	.182	2.445	131	.016	.24
	Trad	2.89		.844					

*Statistically significant at the .002 level.
†These items were reverse-coded for analysis.

In order to hold error rate constant, we divided our α rate of .02 for the overall comparison of attitude toward science class by 10 (for the number of items in this area). Under this constraint, the one item where there was a statistically significant difference was *When I hear the word* science *I have a strong feeling of dislike*. During the SLIDER curriculum, the mean for this item was 3.10, which decreased to 2.83 during the traditional curriculum. The standardized effect size was .30, indicating almost a third of a standard deviation difference on this attitude item. Although there were no other statistically significant differences when holding the error rate constant, there were moderate effect size differences—about a quarter of a standard deviation, favoring attitude during SLIDER)—on the items *It scares me to have to take a science class* and *I have a good feeling toward science class.*

When comparing differences on each science self-efficacy item, we divided our α rate of .02 for the overall comparison of science self-efficacy by 8 (for the number of items in this area). Thus, for each item, α < .025 indicated a statistically significant difference. As illustrated in Table 3, there were statistically significant differences, favoring self-efficacy during the PBL curriculum for the items (1) *I can do my work correctly in science*, (2) *I can do as well as other kids in my science class,* (3) *I can get good grades when I try hard in science*, and (4) *I know I will learn what is taught in science class.* Even for those items that were not statistically significant, effect sizes were moderate to large. Effect sizes were largest for students' confidence that they could get good grades when they tried hard in science, which had a .78 standard deviation difference favoring PBL instruction, and doing work correctly in science, which had a .68 standard deviation difference favoring PBL.

Table 3. Comparisons of Science Self-Efficacy, by Item

		Mean	N	SD	diff	t	df	Sig	SES
I can do my work correctly in science	PBL Trad	3.49 2.88	82	.896 .970	.609	4.96	81	.000*	.68
I can do as well as other kids in my science class	PBL Trad	3.49 3.18	83	.722 .843	.313	3.29	82	.001*	.43
I can help other kids understand the work in science	PBL Trad	3.06 2.80	81	.927 .954	.259	2.01	80	.048	.28
I can be a very good student in my science class	PBL Trad	3.59 3.28	83	.681 .860	.313	2.89	82	.005	.46
I can do the hard work in science	PBL Trad	3.23 2.89	82	.893 .903	.341	2.96	81	.004	.38
I can get good grades when I try hard in science class	PBL Trad	3.77 3.36	83	.526 .820	.410	4.29	82	.000*	.78
I know that I will learn what is taught in science class	PBL Trad	3.49 3.16	83	.687 .757	.337	3.77	82	.000*	.49
I expect to do well when I work hard in science.	PBL Trad	3.65 3.40	83	.614 .748	.253	2.80	82	.006	.41

*Statistically significant at the .0025 level.

Conclusions

Results of this study indicated that students had higher self-efficacy in science and had better attitudes toward science when they were involved in the SLIDER problem-based curriculum that utilizes engineering design as opposed to their traditional science curriculum. Although there were no differences in students' attitudes about science in society, interest in science-related jobs, or interest in science-related activities, we plan to replicate this study next year once the full-year curriculum in in place to determine whether an extended period in the SLIDER curriculum can lead to changes in these areas. We have, in fact, collected baseline survey data on the 7th graders who will be instructed with the SLIDER curriculum in their 8th grade year.

Though this study supports the theory that instruction in PBL can positively affect students' attitude about science and their confidence in their science ability, it should be noted that the study took place in one school with a non-random sample. Additionally, due to constraints at the school, we were not able to implement the full SLIDER curriculum and had to rely on a shorter intervention period. To determine whether effects are consistent as the traditional curriculum is taught during the remainder of the school year, we plan to collect data once more during the second half of the year and compare results of the three survey administrations. Finally, once the full curriculum is developed, we plan to create attitude and interest scales in engineering to determine whether effects are similar in the domain of engineering.

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