Solving the STEM Stigma:

Teacher Preparedness, Manipulative-Based Learning and Inquiry-Driven Edification

ABSTRACT

The Idaho *SySTEMic Solution* (ISS) was a three year research project implemented by the College of Education and the College of Engineering at Boise State University, in partnership with the Meridian Joint School District and educational products and services company PCS Edventures. Funded by the U.S. Department of Education, the ISS was designed to advance the performance and confidence of a select group of 1st-5th grade elementary school teachers in the Meridian School District surrounding the implementation of STEM in the classroom. Answering the nationwide call for an increase in STEM activities at a younger age, the ISS was designed to increase these teachers' comfort levels with STEM through a series of applications surrounding manipulative-based learning in the hopes that it could then be skillfully translated to their classrooms.

To do this, the ISS held three, 3-day workshops for participants over the three year length of the study. In order to measure the outcome of the workshop, pre- and post-intervention assessments were administered to all participants. The primary goal of the summer workshops was to prepare

instructors to teach STEM content through inquiry-driven discovery using BrickLAB®, a hands-on, block-like manipulative provided by PCS Edventures. This white paper analyzes the first three-day workshop. Ultimately, through the workshop and time spent with BrickLAB®, the project focused on the demand for STEM education in elementary-aged learners by first strengthening the instructors' comfort with teaching science, technology, engineering and math in the classroom.

THE ELEMENTARY STEM STIGMA

In the growing technological landscape of today and tomorrow's future, STEM has become a crucial element of early education. From preparing students for emerging sciences to readying them for avenues that haven't yet been invented, it's never been more clear that advanced engagement with and learning of STEM topics needs to be an essential element of every student's education. However, this idea comes to an abrupt halt when we start analyzing the readiness of elementary educators to provide adequate engagement, learning and discovery in the STEM fields. According Nadelson and his team, (2009) "research shows that most K-5 teachers are typically required to complete only minimal coursework in science and mathematics, which constrains their knowledge, efficacy and confidence for teaching STEM." They go on to say, "like much of the general public, (elementary teachers) have limited comprehension about the relationship between STEM concepts and engineering fields and the kind of work and societal contributions made by engineers. Yet, elementary school is a critical time in which students develop foundational understanding of STEM concepts, career options, and inquiry learning" (Nadelson, Hay, Pyke, Callahan, Schrader, p. 2). Meaning, elementary teachers are not prepared to handle the increased need for STEM learning inside the K-5 classroom.

In order to address the growing needs of elementary-aged student involvement in STEM learning and the limited preparation of teachers to provide unbiased, wholesome STEM learning programs and activities, the ISS was born. The first phase of the program, as detailed in the report titled "A SySTEMic Solution: Elementary Teacher Preparation in STEM Expertise and Engineering Awareness", began as a "three-day summer institute for K-5th teachers that focused on enhancing their knowledge and skills for teaching inquiry-based STEM" (Nadelson, Hay, Pyke, Callahan, Schrader, 2010, p. 2). This white paper interprets said report, summarizing its goals, research questions, procedures and results into a definitive conclusion of the effects of a three-day, manipulative-based study emersion study.

A SYSTEMIC SOLUTION

Before the workshop could proceed, the ISS first needed to answer a question of the profound impact of three days of activities on an elementary teacher's professional STEM teaching capacity (Nadelson, et al., 2009, p. 2). This question keyed in on the expectation of current teachers to attend developmental training and seminars to increase their instructional skills, examining whether or not these tutorings were an effective form of amplifying an instructor's capacity to teach. As Bransford and Cocking say in *How People Learn: Brain, Mind, Experience, and School* (1999), "learning takes time… this is particularly true when learning content that is unrelated to prior knowledge," suggesting that a three-day intervention would have little effect on instructional skill. However, according to the research of Bruning, Schraw, Norby and Ronning in *Cognitive psychology and instruction* (2004), "engaging in tasks that are relevant, novel, and applicable increase learner motivation which can lead to a greater probability that a relatively brief instructional intervention can result in significant learning."

"BrickLab reminded me that teaching should be fun. What a great way to incorporate problem solving and communication into curriculum in a highly motivation medium... Loved it"

Wendy Garz

Shadow Butte Elementary

In order to make the most of this research, the ISS put the Bruning et al., research to the test and developed a three-day workshop geared towards increasing the STEM teaching capacity of elementary teachers. To fill the workshop, the ISS looked towards the largest school district in Idaho, the Meridian Joint School District. In order to ensure a diverse group, 39, 1st-5th grade, socioeconomically varied elementary teachers were recruited to participate in the learning experiment (see Table 1). Due to the lack of contribution and involvement in both the pre- and post-tests and general attrition, the final study sample size included 36 participants.

TABLE 1: *Participant Demographics with Averages and Standard Deviations Where Appropriate*

Measure	M (SD)
Male	3
Female	33
Age	40.5 (10.8)
Average Years of Experience	13.0 (8.7)
Bachelor Degree	23
Master Degree	13
First Grade	7
Second Grade	12
Third Grade	4
Fourth Grade	7
Fifth Grade	6

OUTLINING THE GOALS

Through the three-day workshop, Nadelson, et al., (2009) states that the goals of this initiative were to: "increase participants' preparation for teaching STEM content; increase participants' knowledge of STEM careers and in particular engineering; and increase participants' understanding of how to teach using inquiry and manipulatives" (p. 6). In order to guide and track their analysis and results, Nadelson and his team (2009, p. 6) developed three research questions:

1. What were the relationships between years of teaching experience, levels of education, reported comfort with teaching STEM, knowledge of STEM, levels of efficacy for teaching STEM, confidence for teaching STEM, and attitudes toward engineering, of the participants' prior to the Idaho SySTEMic Solution Workshop?

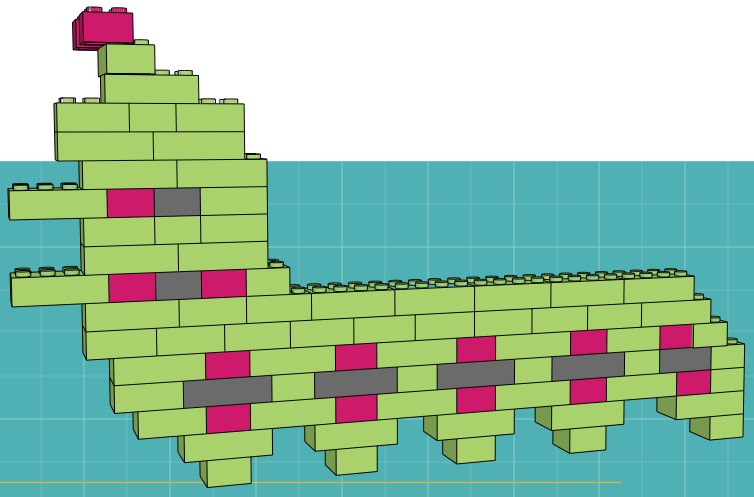
2. Did the participants' experience changes in their levels of efficacy for teaching STEM, confidence for teaching STEM, and their attitudes toward engineering during the Idaho SySTEMic Solution three-day workshop?

3. What were the participants' perspectives of the workshop? In particular what did they find to be helpful for preparing them to teach inquiry based STEM curriculum using manipulatives? (p. 6)

Prior to the workshop, the team developed a hypothesis on the impact the three-day workshop would have on each participant. They stated that, "teachers would experience increases in their confidence, knowledge, and efficacy for teaching STEM" (Nadelson, et al., 2009, p. 6) meaning that a three-day intervention was enough to reveal and increase participants' abilities to comprehend and interact with STEM concepts, allowing them to more easily and confidently apply them in a classroom setting. This idea hinged on the notion that through the workshop's "extensive hands-on activities and experiences using (BrickLAB) manipulatives that could easily be transferred to the teaching of inquiry based mathematics and science" (Nadelson, et al., 2009, p. 6), participants would leave with a higher than anticipated level of understanding, as well as with the skills required to instruct STEM activities.

THE INSTRUMENTS OF ASSESSMENT AND INTERVENTION

In the study, the team used a demographics survey, a confidence in teaching STEM survey, a survey of efficacy for teaching STEM and an evaluation of perceptions of engineering, as well as a post-workshop standard evaluation to gather participant impressions. The demographic survey gathered characteristic data such as: years of teaching, years in position, teaching grade level, experience in prior STEM professional development initiatives and two questions that had participants rate their knowledge and comfort levels for teaching STEM topics.



During the workshop, the ISS used a mixture of small group discussions, hands-on activities, individual assignments and whole group lectures. Opening with engineering faculty and research staff presenting on the art and creative aspects of engineering, as well as engineering's everyday applications, the ISS worked to transform the participants' previous notions of engineering through the lectures' guided interactions with PCS BrickLAB® curriculum and lessons. As Nadelson, et al., (2009) say, "BrickLAB® curriculum is rich with engineering connections, such as building skyscrapers, bridges and structures, solar and wind energy, and manufacturing and systems... Our intent was to make the participants as familiar as possible with the resources and process of implementing inquiry based curriculum using the BrickLAB® manipulatives to teach STEM curriculum" (p.9).

On the first day of the workshop, the participants were given activity books for their particular grade, which provided them with a resource for further development. PCS Edventures also supplied a structure for paralleling the school district's learning standards. As Nadelson, et al., (2009) states, "alignment became an important aspect of the participants' curriculum development and planning, as teachers were encouraged to continue refining and expanding the alignment of the curriculum" (p. 9). Day's two and three of the workshop had the teachers engaging in hands-on activities, as well as attending lectures provided by Boise State University faculty and PCS Edventures staff and curriculum planning seminars meant to expand their capacity for efficiently teaching inquiry-based STEM curriculum using the BrickLAB® manipulatives. On top of experimenting, interacting and creating with the BrickLAB® products in day two and three, day one had participants attending lectures that best prepared them for the ins-and-outs of utilizing manipulatives like BrickLAB® in the classroom.

COMPILING THE DATA

At the completion of the three-day workshop, the data gathered through the various, previously listed, surveys was compiled and analysed alongside the project's original three research questions. In order to answer their first research question, Nadelson, et al., (2009) first calculated, "the correlations between our pretest measures, our demographics measures, and our teacher comfort and knowledge for teaching STEM content measures" (p. 10), highlighted in Table 2.

"Designing, creating, building, testing, redesinging, evaluating - The workshop allowed me to vividly experience all those STEM elements. And that experience was...FUN which makes me want to use it in my classroom."

Mark Morgan

Dora Erickson Elementary

TABLE 2: *Correlations of Pre-Workshop Measures, Demographics and Comfort and Knowledge of STEM (n=36)*

Variable	1	2	3	4	5	6	7	8	9
1. Age	—	.14	.72**	-.01	.19	.12	.05	.34*	-.14
2. Education Level		—	.18	.15	.18	.29	.02	.07	.10
3. Years Teaching			—	-.04	.24	.10	.20	.39*	-.04
4. Grade(s) primarily Taught				—	-.18	-.17	-.03	-.18	-.20
5. Comfort Teaching STEM					—	.86**	.39*	.63**	.04
6. Knowledge of STEM						—	.38*	.55**	.03
7. Efficacy Teaching STEM							—	.43**	-.09
8. Confidence Teaching STEM								—	.07
9. Engineering Attitude									—

$*p < .05$; $**p < .01$

Overall, this correlation found the most significant links between 1.) comfort teaching STEM and knowledge of STEM, 2.) comfort teaching STEM and confidence teaching STEM, 3.) knowledge of STEM and confidence teaching STEM and efficacy teaching STEM and confidence teaching STEM, as showcased in the table by the double asterisked ($p < .01$) values. They also found that, "overall, years of experience and age were predictors of our participants' confidence for teaching STEM. … Participants' levels of education, grade level primarily taught, and attitudes toward engineering were not found to be significantly correlated with any other measures" (Nadelson, et al., 2009, p. 12).

The second research question was answered through a comparison of the pre- and post-test scores of the three measures of the study (Efficacy For Teaching STEM, Confidence for Teaching STEM and Attitude Toward Engineering), (see Table 3).

TABLE 3: *Pre-Test, Post-Test Means and Standard Deviations of the Three Study Measures (n=36)*

Measure	**Mean (*SD*) Pre-Test**	**Mean (*SD*) Post-Test**
Efficacy For Teaching STEM	89.77(*9.34*)	96.5(*9.57*)
Confidence for Teaching STEM	141.69(*16.41*)	150.3(*11.85*)
Attitude Toward Engineering	101.17(*5.47*)	110.51(*7.33*)

As a result of the three-day workshop focused on inquiry-driven instruction and manipulative-based learning with BrickLAB® Bricks, the 36 participants saw a drastic increase in both efficacy and confidence for teaching STEM, as well as in their attitudes towards engineering, thus confirming that brief intervention that is relevant, novel, and applicable can have a significant impact on learners.

The third research question analysed the answers to the select response and free response questions found on the workshop evaluations. The overwhelming response was "that the participants felt that the hands-on activities and curriculum planning were the most valuable activities of the workshop. All participants strongly agreed that time spent working with the manipulatives was beneficial to their preparation for teaching STEM with the workshop associated resources (manipulatives and activity workbook). In contrast, only about two thirds of the participants agreed that the lectures were applicable to their preparation for teaching inquiry based STEM" (Nadelson et al., 2009, p.12-13).

In the participant response to the question of what was *positive, negative, and interesting,* Nadelson et al., concluded that these answers again, " revealed that time spent interacting with the manipulatives was perceived as very positive and beneficial," also concluding that, "The participants were positively influenced by the engineering presentations" (2009, p. 13). Finalizing the analysis of the participant answers, Nadelson et al., (2009) concludes, "these comments reveal an increase in familiarity with inquiry, especially when it involved using manipulatives. Another major theme was the connection between the workshop and the participants' classrooms. This is evident from the following passages, "How this connects with the classroom" and "Activities that are able to be used" and "Classroom management hints." Preparing teachers to teach inquiry-based STEM using manipulatives was the goal of our workshop and it appears we achieved that objective" (p. 13). Through a three-day workshop and simple interaction with BrickLAB® manipulatives, the researchers were able to increase efficacy and confidence for teaching STEM, as well as improve the participant's previous notions of engineering.

PIECING IT TOGETHER

In order to solve the STEM stigma — combatting the growing need for a dramatic increase in the incorporation of STEM in elementary classrooms and the aversion, inexperience and lack of confidence in teaching STEM found within K-6 instructors — elementary teachers need consistent and adequate exposure to the STEM fields. Due to the minimal STEM learning required to receive a teaching certificate, this exposure needs to be supplemented outside of higher academia in order to meet increasing demands. By utilizing smaller, well-designed educational initiatives, like the ISS did with BrickLAB® manipulatives, administrators can drastically increase their instructors efficacy and confidence for teaching STEM. Both versatile and engaging, BrickLAB® manipulatives were engineered specifically as an answer for the expansion of elementary STEM learning. As showcased by the research, merely engaging with these manipulatives in a positive environment had a radical effect on instructor confidence, which almost immediately translated into a change in perception, efficacy and comfort with STEM, a change that seamlessly folds itself into the K-6 environment.

References

Bransford, J., Brown, A. L., & Cocking, R. R. (Eds.). (1999). *How people learn: Brain, mind, experience, and school.* Washington, D.C.: National Academy Press.

Bruning, R.H., Schraw, G.J., Norby, M.M., & Ronning, R.R. (2004). Sensory, short term, and working memory. In R.H. Bruning, G.J. Schraw, M.M. Norby, & R.R. Ronning, *Cognitive psychology and instruction* (pp. 14–35). Upper Saddle River , NJ : Pearson Education.

Nadelson, L., Callahan, J., Pyke, P., Hay, A., & Schrader, C. (2009). A SySTEMic Solution: Elementary Teacher Preparation in STEM Expertise and Engineering Awareness. *American Society for Engineering Education,* 1-13. Retrieved April 14, 2017, from http://scholarworks.boisestate.edu/cifs_facpubs/35/

Nadelson, L., Hay, A., Pyke, P., Callahan, J., & Schrader, C. (2010). Teaching Inquiry-Based STEM in the Elementary Grades Using Manipulatives: A SySTEMic Solution Report. *American Society for Engineering Education*, 1-19. Retrieved April 27, 2017, from https://works.bepress.com/louis_nadelson/10/.

Thayne Casper
Chief Author and Editor of Creative Content at PCS Edventures!