Learning by Making: i3 Impact Study

Executive Summary

The Learning by Making (LbyM) project is funded by the U.S. Department of Education's Investing in Innovation Fund (i3). As a five-year development project (2014-2018) Sonoma State University (SSU), in partnership with high-need schools and districts in Mendocino County, has been developing an innovative, integrated high school Science, Technology, Engineering, and Mathematics (STEM) curriculum.

The curriculum consists of Disciplinary Core Ideas (DCIs) in earth science and biology as described in the Next Generation Science Standards (NGSS, 2013) and includes an easy-to-use Logo programming language that conducts data transfer and network communications in support of student-designed investigations. It integrates the NGSS Scientific and Engineering Design Practices and the Common Core State Standards in Mathematics (CCSS-M) into a modified project-based learning approach whereby mathematics and science concepts are integrated with technology as students design and conduct experiments related to real-world problems. During LbyM investigations, students write Logo code to read the sensors and obtain data. Further, students use basic coding to perform individualized experiments, create simulations, and explore models. They analyze and interpret data while using mathematics and engage in computational thinking. Throughout the course of the project, the participating teachers have played an integral role in the development of the curriculum. Teachers provided consistent and detailed feedback to SSU which helped their team modify LbyM to better fit the needs of teachers and students. Additionally, teachers contributed directly to experiment design and curriculum content, resulting in a STEM course fortified with teacher input.

During the 2016-17 academic year, WestEd conducted a rigorous study of the LbyM STEM curriculum in rural California high schools. The focus of the study was on the impact of the curriculum in increasing rural high school students' mathematics and science outcomes and enhancing their teachers' instructional practices and technological competency. Specifically, the study applied a quasi-experimental design to address the following research questions:

Confirmatory Research Questions:

> **RQ1:** Does LbyM influence mathematics performance of 9th to 12th grade students compared to mathematics performance of 9th to 12th grade students in the business-as-usual condition?
> **RQ2:** Does LbyM influence science performance of 9th to 12th grade students compared to science performance of 9th to 12th grade students in the business-as-usual condition?

Exploratory Research Questions:

> **RQ3:** Does LbyM influence high school mathematics and science teachers' competence in delivering computational thinking lab-based STEM curriculum?
> **RQ4:** Does LbyM increase high school students' interests in STEM and a STEM career?

Study Design and Methodology

The LbyM impact study utilized a quasi-experimental design. Teachers were recruited from high-need rural high schools in Mendocino County, California. The final analytic sample included the recruited teachers and their students: 98 students in six LbyM STEM classes from five schools and 52 students in six

comparison classes from three out of the five schools. In the 2016-17 academic year, students in LbyM STEM classes participated in the LbyM STEM curriculum, which comprised six units and focused on the three-dimensional learning strategies of the NGSS, computer programming language, and problem solving and troubleshooting. Each unit included 11 components: Objectives, Material Lists, Common Core Standards, NGSS, Background for the Teacher, Logo Vocabulary, Troubleshooting, Lesson (Procedure, Foundations, Going Further Extensions), Solutions, Teacher Materials, and Student Handouts. Although the curriculum provided a suggested pacing guide for each lesson, it allowed teachers to adapt lessons to their own style and needs. The comparison group, or "business-as-usual" group, received the instruction they would normally receive if the study were not taking place. Data were collected from pre/post student math and science content assessments, pre/post student STEM attitude surveys, pre/post teacher technology and instructional practice surveys, teacher logs, classroom observations, and teacher interviews.

Findings

The results indicate that the LbyM curriculum was positively associated with significant gains in students' science content knowledge, as measured by science assessment items selected from the Certica Assessment Item Bank. On average, students who were exposed to the LbyM curriculum outscored their comparison group peers on the science assessment by 7 percentage points, a statistically significant result. The LbyM curriculum was also positively associated with gains in students' math content knowledge, as measured by math assessment items selected from the Certica Assessment Item Bank. On average, students who were exposed to the LbyM curriculum outscored their comparison group peers on the math assessment by 4 percentage points.

Findings from teacher surveys and interviews suggest that the LbyM curriculum that was developed by SSU helped teachers integrate the NGSS into classroom instruction, and increased their comfort with project-based learning. The LbyM curriculum supported teachers in applying student centered instructional practices. Teachers also reported spending more instructional time supporting students to collect, organize, display, and present data.

Findings from observations, teacher focus groups, and interviews suggest that the LbyM curriculum has helped low-achieving student improve math understanding. Students were highly engaged with the LbyM curriculum and demonstrated increased confidence and problem solving stamina. Teachers reported that some individual students who typically struggle to participate in class exhibited higher levels of participation in LbyM and even demonstrated leadership. The LbyM curriculum was accessible to students with different abilities. Teachers reported that some students with special needs, while still requiring extra attention, remained engaged in curriculum and were even quicker to complete certain activities than the other students.

Some quotes from teachers in the study that support these findings include:

> "One of the things that I noticed last year but I feel like it's really happening [now] is that the kids are learning a lot of math. I feel like there's such a connection between what we do in this class…So I just think that the math that's embedded in the curriculum is really incredible. It's accessible to a real spectrum of kids with different math skills."

> "The idea of giving [students] a little bit of information about a thing, letting them practice it, seeing how to build the skill, and then let them come up with their means of going

through a project. I felt like if I didn't have [LbyM]…I would have a hard time making the transition to the whole project-based learning thing."

"Kids would come in a few minutes before school started. They would get their laptop out, and they would start working, and they would just be here. And I've never had that in a first period class, where the kids came, and they just started working without any instruction from me."

"I've become more student centered. It may have been part of this program, too, because this program is very student centered."

"I love when I step back, because really I'm steering the ship, but they're really the ones that are making it go. And I like that."

Conclusion and Directions for Future Research

The 2016-17 study of LbyM was designed to test whether the curriculum impacts student performance in math and science, to determine the extent to which teacher instructional practices and technological competencies are influenced by the curriculum, and to gauge whether the course impacts student attitudes toward STEM. Student outcome data revealed that of the 9th through 12th grade students in the sample, LbyM students scored statistically higher on the science content assessment following the intervention than students in the comparison group. Findings on teacher growth indicated that teachers are dedicating more class time to data collection, analysis, and display, and that their own comfort with technology has increased since teaching LbyM. Teachers agreed that LbyM is especially beneficial for many students who do not excel in traditional high school classes. Analysis of qualitative data shows high levels of student engagement, and an increase in students' stamina for problem solving and overcoming unfamiliar challenges in the classroom.

Driven by impact study findings that students benefit academically from the LbyM STEM curriculum, SSU and WestEd have continued to monitor indicators of academic growth and engagement for LbyM students during the 2017-18 school year. Already, this year's students have expressed enthusiasm for this innovative curriculum. Not only are they excited by the student-driven nature of LbyM STEM, but they also feel that LbyM supports them in building 21st century skills (Partnership for 21st Century Learning, 2015) and in preparing for college and career. Some of the recent student comments include:

"We kind of get some more of the skills other people don't get in high school. Like, how many other classes are there where you get to like, do coding and do wiring and stuff like that? So, I feel like we just get a lot more skills that other people don't have. And I think that really stands out."

"I like how if there is a problem, it's not like on the paper. You have to solve it, you have to go deeper to think about what's wrong."

"This coding stuff is gonna make a lot of stuff obsolete, and so college and other stuff will be looking for students with experience with technology."

By refining and scaling LbyM, this project hopes to expand the reach of this innovative STEM curriculum, and make high quality, standards-aligned STEM learning accessible to more students.