MAkerspaces Promoting Learning and Engagement (MAPLE) Project
Year One Annual Report

09.2018

1. What are the major goals of the project?

The aim of this project is to answer preliminary questions about instructional strategies to support students with learning disabilities in classroom-based makerspace activities: (1) what learning barriers are present during the design-redesign and problem/project process common to makerspace and early STEM experiences, especially for struggling learners, (2) how can instruction that supports metacognitive strategies be integrated within typical K-12 classroom makerspace activities to address those barriers, and 3) how can the effectiveness of those strategies be evaluated by measuring engagement and learning. We believe this work is particularly salient given national efforts that inform DRK-12 research, such as the Reinforcing Education Accountability in Development (READ) Act, which stresses the development of comprehensive strategies to address key barriers to retention and completion (HR601).

2. What was accomplished under these goals?

2.1 Major Activities:

Major activities of Project MAPLE include continued definition and review of the problem space, research instrument development, observations and data collection, analysis, and dissemination. Significant progress and accomplishments have been made in year one on instrument development and observations.

Instrument Development.

> Data collection demanded the development of specialized instruments to assess the types of challenges students with learning disabilities (LD) and those at risk for academic failure face during makerspace activities, as well as the pedagogical approaches that teachers can use to address those challenges. The entire team contributed to instrument development, research on strategies and characteristics to be included for assessment, multi-tiered approaches to breaking down

metacognitive strategies, barriers to learning and other areas of focus. To date, the following types of instruments have been developed and piloted: teacher and student observation instruments, teacher interviews, and student surveys. Supporting this process included review of existing tools, used primarily as coding exemplars, the construction of coding and terminology guides and sample protocols for work in the field. This instrument development process required more iteration and attention to detail than originally anticipated, largely due to the complexity encountered in describing metacognitive strategies within the context of makerspace activities. The Teacher Observation Rubric is available as a product in this report.

Observations and Data Collection

Year 1 observations and data collection primarily focused on: (1) testing instruments, (2) training research assistants in consistently collecting data in an efficacious manner, (3) familiarizing the teachers with the research team and data-collection process as well as the scope and definition of "makerspace activities", and (4) understanding barriers to engagement and performance within these activities. Project MAPLE is grounded in previous research focused on community-wide engagement for diverse learners and learning environments (e.g., Co-PI Israel's NSF project TACTIC NSF No: #1639837). In the majority of classrooms, Year 1 observation and data collection was focused on establishing a foundational understanding of barriers to engaging in makerspace design learning and problem solving ways of establishing more robust experiences, given the brief periods of time devoted to hands-on and computer-based making in the classrooms. Additionally, the classroom observation tool needed to be sufficiently refined to function in both a formal, standards-driven science classroom and flexible STEM classes that were not part of core curriculum.

One of the research sites is a full-time, dedicated Science classroom where makerspace activities are sometimes incorporated into an 8th grade class. It is here that academically diverse students have been most frequently observed working in a standards-based core curriculum setting with opportunities for makerspace activities. The other three research sites are middle school classrooms in which a district-wide STEM lab course focuses on extended design activities at the 7th and 8th grade levels. This STEM lab course is not core curriculum and is not necessarily standards-based, though the teachers make every effort to incorporate relevant standards. As a non-core course, it is not required for all students; some students are pulled out for programs such as reading recovery, foreign language and band.

Several iterations of data collection occurred in Year 1 as the team explored the dynamics of the classrooms as well as how to best observe in each classroom. They assessed and revised the instruments and developed skills in qualitative data collection. In initial classroom observations co-PIs and the evaluator observed alongside the graduate student research assistants, in order to establish a process and mentor the RAs in observation and documentation techniques necessary for reliable data collection.

Observers in classrooms took field notes that were then organized for reporting using a Teacher Observation Rubric. Year 1 focus was on observation of teachers and the context of the entire class. The data collection instrument focused on the key areas of teacher strategies:

- Provision of structure and consistency
- Scaffolding the learning process
- Supporting thinking and metacognition
- Accommodations for at-risk students and those with learning disabilities
- Barriers (e.g., language, technology, structural limits like short class times)

Teams of two observers per day visited classrooms for a total of 50 classroom visits during Year 1. Grade levels observed were middle school 7th and 8th grade STEM classes. Class sizes varied greatly, ranging from a low of 7 students to a high of 24 students. During Year 1 learners with identified learning disabilities and students at-risk were not specifically targeted during data collection. Year 2 will explicitly identify these students and focus on evidence of benefits from metacognitive teaching strategies within makerspace experiences.

Data was also collected by recording one-on-one interviews with teachers. All interviews followed a protocol tuned to be cohesive with the areas of focus in the observation guide.

Teachers in the four middle school settings ranged in years of experience from from a first year teacher to a veteran teacher with more than 20 years experience. While it was not specifically asked how many teachers received copies of IEPs, were included in IEP meetings, or background information on at-risk students in RtI, observers in conversation with teachers, indicated that teachers may receive accommodation information for students with disabilities, but there were no indications teachers were included in IEP meetings.

Observation and data collection in the non-core STEM class learning settings proved challenging, both in terms of the dynamics within classrooms and in the identification of makerspace activities that would best support data collection of appropriately hands-on and computer-driven activities. The intricacies of design, setup and implementation of learning experiences in classrooms were often observed to have many distractions, confusion and considerable variance in student participation, which made it difficult to collect data at times.

Observers also noted use of minimal accommodations in classrooms. Students may receive 1:1 paraprofessional support or they may receive reminders, but this was not often observed. Some teachers did not believe many accommodations were needed for students since STEM does not require much reading or writing.

Lastly, data was collected to test out the C-COI (Collaborative Computing Observation Instrument) screen capture data collection procedures in the science classroom and one STEM classroom. RA's also spent time getting to know teachers and working out a collaboration model for planned future co-development of metacognition-enabling curriculum.

Analysis

Data analysis began in May of 2018 and is ongoing. Data is being coded using the Dedoose software, a collaborative platform for classifying, organizing and coding of qualitative data. Preliminary analysis of data will emphasize the use of evidence to further refine our research questions and summarize barriers to metacognitive strategy instruction to support students with learning disabilities and at-risk for academic failure. The analysis is currently focused on identifying systemic, pedagogical, and student-level barriers encountered by struggling learners during makerspace activities.

The team has produced an expanded coding guide, continues to add to and detail the accompanying terminology guide, and has collaborated as a 4-person team in the effort to code, cross-code, and triangulate data to ensure reliability. All research assistants were trained on the coding of qualitative data using *The Coding Manual for Qualitative Researchers* (Saldana, 2015).

2.2 Specific Objectives

To support the iterative research development process we continually review and clarify approaches to address our main objectives that will form an empirical basis for future work:

Makerspace Curricular Choices

It is important to work with models of makerspace curriculum that are both accessible and comparable, so our study can yield results that are applicable for a variety of school settings. Our first objective is to fit makerspace learning experiences into existing teacher-identified curricular needs and STEM subject areas identified in collaboration with our partner schools. We will also ensure teacher objectives and interests inform our chosen activities and continually work with them throughout the development and execution process.

Instrument Development and Adaptation

Multiple instruments will be used to measure pertinent metacognitive processes. We anticipate a focus on persistence (attitudes about making), iteration (productive struggle) and intentionality (plan with incremental steps). Instruments will include student observation protocols, teacher observation protocols, the Collaborative Computing Observation Instrument (C-COI), a teacher interview protocol, and an artifact-based interview protocol.

Observations and Pilot Study

In pre-pilot activities observations will be analyzed in order to determine barriers to successful implementation of classroom-based maker activities, barriers to student engagement and academic achievement, and to refine instruments that will document and measure target metacognitive strategies. We will cultivate initial support structures, such as co-constructed makerspace activities, and accompanying metacognitive strategies to facilitate increased engagement and learning for students at risk for academic failure. We will then pilot the implementation of these metacognitive strategies and begin to iteratively refine them. These progressive observations and studies will result in a revised set of metacognitive strategies and support materials for implementing making experiences for struggling learners.

Communication and Dissemination

Dissemination efforts will include:

- Websites with curricula and strategies, alongside other resources associated with our project.
- Research findings via presentations and publications in peer-reviewed practitioner and research journals.
- Research briefs that describe components of our work in progress.
- Workshops with key middle school makerspace educators with academic and vocational partners, such as the FabLearn community of scholarship or University of Illinois Extension 4H Educators.
- Webinars for those interested in accessible middle school makerspaces for diverse learners, focused on lessons we are learning and practical advice for bringing accessible and engaging makerspace instruction to broad audiences.

2.3 Significant Results

While our research is still in progress and exploratory, Year 1 revealed several conclusions about barriers to classroom-based makerspace activities, and how teachers engage in and choose makerspace learning activities. These findings are directly leading to changes in instrument formulation and implementation in year 2, especially for teacher professional development and the inclusion criteria for makerspace activities and metacognitive learning strategy supports within classes.

Teacher Factors

Classroom observations revealed that ***teachers may carry out some metacognitive strategies with struggling learners, but they appear to be coincidental rather than planned***. Teachers have not been observed articulating steps used to carry out strategies like scaffolding, using failure as a learning opportunity, engaging in learner-driven practices to support student participation, or learning and conceptual understanding in scientific inquiry. Lesson plans were often not consistently present, and while one of the school districts provided "guidelines" for the non-core STEM class, which is comprised of many makerspace activities, teachers tended to choose thematic units where students were limited to reading from handouts and project worksheets without identified connections to standards or learning goals.

The foundational aspect of makerspaces and the keynote metacognitive strategy of play leading to intentional and iterative tinkering were largely absent, thus student engagement varied considerably. Disengaged students demonstrated a range of behaviors, from passive resistance to activities to disruptive behavior that affected the entire class. At this time our team can begin to postulate why barriers exist. One factor may be the ***lack of teacher***

awareness and training around metacognitive strategy and the deeper foundational underpinnings that support these processes.

Another factor lies in the ***attitude and openness*** when comparing a longtime teacher with a new teacher. We have this situation in our project. A new teacher comes with a different experience of learning and may be equipped with a more progressive and creative desire to try new approaches. The new teacher may not feel bound by the more traditional system of teaching and learning and is eager to find innovative ways to approach all students including those with learning disabilities and at-risk. While this may be a factor we also see in our project a very seasoned and experienced teacher who is actively and regularly engaged with students, asks questions, asks for new strategies and resources to help implement change, leading to more opportunity for makerspace activities in the classroom. This experienced teacher engages students at a level of inclusiveness that is encouraging to building the self-esteem and empowerment of every student, especially those with learning disabilities and at-risk for academic failure.

It is also important, when considering the research questions, to be aware that each of the teachers involved in this project operates in "isolation." The ideas behind STEM education and makerspaces are new to a high percentage of their colleagues, thus ***they lack the internal systemic supports and peer networks*** that encourage quality teaching and shared learning practices. As cited in the literature, even as the climate becomes more amenable to makerspace instruction, there remain few investigations of how makerspaces can be made accessible to a broad range of learners in *public* school settings.

Reflections and observations during teacher professional development also supported these conclusions. As teachers engaged in various activities they too displayed a range of emotions similar to those of students: frustration connecting new learning ideas to making, challenges in problem-solving skills, lack of persistence, dependence on a partner for answers, difficulty working with a partner, lack of enthusiasm, and the appearance of being overwhelmed. Other teachers were enthusiastic, worked from prompts, made and re-made, and made insightful observations like "If this frustrates me how would a student feel?" These teachers went beyond the suggested activity to apply new strategies.

Classroom Factors

In half of the classrooms participating in Project MAPLE, environmental conditions do not facilitate the establishment and perpetuation of makerspaces and a community of makers. ***Space is limited, classrooms may be removed from the larger school community, classrooms may be ill-equipped to facilitate the set-up required of a true makerspace, classrooms within the school setting may be situated in "pass-through" areas where***

other groups of students are constantly coming and going to other classes. These types of disruptions are especially frustrating to students with learning disabilities and at-risk. Some classrooms struggle with a lack of resources to carry out effective maker activities and teachers do not receive funding that allows for adequate preparation and hands-on experiences. Teachers do their best to use all space wisely, but the skills we strive to see in students like persistence, iteration, and intentionality are influenced by the setting, tone, and character of the classroom.

It became apparent during the 50 observations conducted by the team in Year 1 that few of what the literature defines as making experiences are occurring in classrooms. Contrary to the literature ***we do not see an alignment of the standards-based movement and the Maker Movement*** that would foster creative solutions through innovative design (Bajarin, 2014). There is not the presence of a joint movement aligned to both encourage problem-solving, project-based learning, design solutions, student agency and autonomy, and high levels of hands-on engagement (Martin, 2015).

Classrooms are experiencing rising numbers of students in STEM classes and classroom environments are rarely structured for makerspace activities. Teachers expressed a sense of frustration because they were not well-supported by administration as a non-core class..

Systemic Factors

The struggle to instill metacognitive strategy instruction and makerspace activities in STEM classrooms is difficult due to a ***lack of administrative and systemic support***. While school systems attempt to act in good faith, it is the case that *public* education, at this period in our history, is undergoing change that challenges its existence. Large class sizes and short durations (both in terms of daily periods and systems like quarterly rotations) exist as tremendous global barriers to project-based, iterative learning.

We also discovered that teachers in makerspace classrooms find themselves in somewhat ***tenuous positions in regard to performance standards*** linked to their personal evaluations. The standards in the makerspace classrooms fall under district standards for engineering process and computational thinking including decomposition, pattern recognition, abstraction and algorithms. However, in both districts teachers' personal evaluations are affected based on the percentage of achievement of learners. Many of these classrooms serve students that "don't fit elsewhere" like music, art or drama. The classrooms have disproportionate numbers of students at-risk of failure or with identified learning challenges. Administration runs from highly supportive and aware of the activities and value of makerspace classes to uninformed and without the time or inclination to learn what goes on in these classes and the major performance areas they target.

Barriers to making and student achievement in these classes are recognized by school administration and teachers to some extent. However, barriers that might be overcome may continue due to school policies and expectations. Makerspaces are active learning environments typically conceptualized as "doing" spaces. Students are not expected to sit quietly in rows and absorb information. The need to balance student freedom to learn in an experiential manner is sometimes challenged by their behaviors and what is acceptable in more traditional learning environments. .

2.4 Key outcomes or Other achievements:

The week-long teacher professional development workshop held at the Champaign-Urbana Community Fab Lab (summer 2018) appeared to be successful in modifying teacher attitude and intention and the project team learned some important lessons as well. Teachers were administered a pre- and post- questionnaire. Responses appeared "modest" and general in the pre-questionnaire. For example, in response to the question "What are your goals for this week of professional development?" teachers responded with general interest in learning new things and " 'tricks' to get students motivated to take ownership in their learning

In the post-questionnaire responses demonstrate enthusiasm and reflect positive learning experiences. For example, one teacher stated "I wanted to get an idea of technology I can use in my new makerspace, and boy did I get it! I have pages of notes with ideas and ways to implement it which is a huge bonus!"

Also, after the workshop teachers demonstrated positive intentions for modifying their teaching based on topics covered in the workshop:

- I've gotten a lot of ideas for changing the curriculum I plan to teach. The UDL chart will also be my best friend when planning (and hopefully before doing)
- More creativity and fewer "cookbook" projects
- Be more tech-based; have videos to reinforce/introduce ideas. Have more opportunities for student choice
- More purposeful alternative assignments/activities for these students
- Let the students have more input

2.5 References Cited

Bajarin, T. (2014, May 19). Why the maker movement is important to America's future. *Time*. Retrieved from http://time.com/104210/maker-faire-maker-movement

Flavell, J. H. (1987). Speculation about the nature and development of metacognition. In: F. E. Wernert and R. H. Kluwe (Eds.), Metacognition, Motivation and Understanding. Hillsdale, NJ: Lawrence Erlbaum Associates.
Martin, L. (2015). The Promise of the Maker Movement for Education, *Journal of Pre-College Engineering Education Research* (JPEER): Vol. 5: Iss. 1, Article 4.
Saldaña, J. (2015). *The Coding Manual for Qualitative Researchers.* Sage.

3. What opportunities for training and professional development has the project provided?

This project supported two opportunities for professional development for participating teachers and graduate research assistants. One was a week-long workshop led by the MAPLE project team at the Champaign-Urbana Community Fab Lab. This workshop focused on making, design, and educational topics related to teaching struggling learners and students with learning disabilities. The second opportunity was the Maker Educator Collective Bootcamp at the Pathfinders Summer Institute 2018, held at Indiana University Bloomington and sponsored by Infosys Foundation USA and others (http://www.infosys.org/infosys-foundation-usa/pathfinders/#maker-educator).

3.1 Fab Lab Workshop

Goals for this professional development week (July 23-27, 2018) with all participating teachers (4 middle school teachers) and 1 school technology coordinator included:

- Focus on teaching methods, specifically those that most impact LD and at-risk student populations including Universal Design Learning, Culturally Responsive Teaching, Positive Behavior Coaching
- Learn it + Teach it and the methods of Do It Yourself (DIY) + Do It with Others (DIWO)
- Maker technology implementation plan
- Sustainability of makerspace learning through district administration with diminishing reliance on the University and/or grant support over time

Topics

Key presentations and sessions called upon professors and experts from many units at the University of Illinois included the following:

- Core Principles to Promote Learning in School-Based Makerspace. How do we attain our goals?

- Overview of barriers to student success on maker activities; how our own classroom observations are reflected in the literature, led by graduate research assistants Cheng eun Lee and Noah Samuel
- Positive Behavior Support Coaching, led by Gakyung Jeong (Ph.D. student in special education)
- Universal Design Learning (UDL), led by Drs. Lynn Burdick and Johnell Bentz (staff in educational technology and faculty in special education)
- Integration of hands-on making activities teachers can immediately use in the classroom that address district performance guidelines, e.g., Makey-Makey, Little Bits, experience with FabLab deployment kits; led by graduate research assistants Heather Arnett and Dot Silverman, and PI Ginger
- Creativity and Playfulness; Ken Robinson's premise that schools kill creativity, overviews of observations reflections on Positive Behavior Coaching, 3-D modeling tasks, importance of modeling and mentoring of teaching staff.
- Accommodations for at-risk or LD students, led by Dr. Johnell Bentz
- District level involvement and support of makerspace classrooms
- Cultural Relevance in the design and implementation of makerspaces, led by Dr. Will Patterson

Makerspace Activities

Teachers participated in Makey-Makey electronic controller design activities, allowing them to practice in an open learning environment. Activities ranged from construction of circuit boards in novel ways, e.g., a bracelet, dinosaur games, control boards, remixing functions like music, bird sounds...to activities like constructing a music controller keyboard. This could be used for children with functional learning skills and other students with disabilities. As they engaged in activities teachers asked questions and raised issues related to assessment, inquiry, collaboration, persistence and requisite knowledge

Universal Design Learning (UDL) Session

The UDL presentation was titled "UDL Curb Cuts for Learning." The expert presenters focused on the importance of UDL providing access and opportunities for learning. UDL also addresses the civil rights of those with disabilities. The group was asked to consider the principles and practices of UDL with its curriculum that demonstrates equal opportunity, a flexible approach, and a blueprint that works for everyone.

Cultural Relevance of Makerspace Learning Session

Makerspace teaching should be culturally responsive teaching. Makerspaces draw a highly diverse group of learners of different backgrounds. Different learners require differentiated instruction principles that links content-delivery to assessment-with students' ancestral and contemporary cultures. Two experts presented on cultural relevance, innovation, entrepreneurship and the ways makerspace learning can lead to careers in engineering, business, art and technology. Teachers were encouraged to contextualize learning methods that draw diverse groups of students to re-think learning outside the realm of traditional schooling and to draw from a variety of disciplines to address contemporary issues impacting student's communities and environments around the world.

Supporting Makerspace Classrooms

The week of professional development offered teachers the opportunity to work as individuals or in small groups with staff to plan the feasibility of new projects and approaches in the classrooms. Teachers were invited to explore the FabLab and look at tools and resources they already have or may acquire for their classrooms to enhance making for every student. Each teacher was able to meet with the PI to discuss needs, budget allotment, and planning. Teachers have funds to purchase new tools and resources. Planning and discussion of possible uses facilitates the wise use of funds and allocates funds that can benefit all students, not a select few. Project MAPLE staff were available throughout the days with ideas and hands-on experiences that teachers could quickly learn, make and replicate in their classrooms. Out of the box thinking was encouraged.

3.2 Maker Educator Collective Bootcamp

Two project participants were able to attend this bootcamp, one teacher and one graduate research assistant. They shared their experience and materials with the project team at the week-long Fab Lab workshop described above. Sessions included demonstrations and practice on prototype activities, and topics on pedagogy such as Why Making, Visible Thinking Routines, Integration of Content, Digital Design, and Assessment.

4. How have the results been disseminated to communities of interest?

Two conference proposals have been accepted to disseminate findings from the project (Teacher Education Division of the Council for Exceptional Children; TED-November 2018 and the National Council for Exceptional Children; CEC-February 2019). Additionally, a manuscript, "Understanding instructional challenges and successes to including middle school students with disabilities in makerspace activities: A cross-case analysis", is nearing completion and is anticipated to be ready for peer review by mid-September 2018.

Project MAPLE was presented both during the proposal and Year 1 stage at the University of Illinois iSchool Research Showcase as an academic poster. See Ginger, J., Israel, M., Teasdale, R., Bievenue, L., Linder, S., Bentz, J. (2016-17). "Towards a Progressive Model for Metacognitive Strategies and Makerspace Learning." iSchool Research Showcase, UIUC, 10.2016-17.

In addition, the MAPLE grant team presented on the project research design and in-process data collection instruments at a full day workshop at the Museum of Science and Industry (MSI) Wenger Family Fab Lab in Chicago. See http://cucfablab.org/research/project-maple/ for the presentation.

Other dissemination efforts include: the development of a project website (http://cucfablab.org/research/project-maple) and dissemination of research findings to participating teachers as part of the summer 2018 professional development.

5. What do you plan to do during the next reporting period to accomplish the goals?

As we enter Year 2 of Project MAPLE, it is with the understanding that we will find variability in situations from school to school. Our task is to concentrate on further investigating our research questions and examine what has been evidenced through data collection and research literature. Our goal is to assemble a "microcosm" of high quality practices aligned to the theoretical and empirical framework on Makerspaces in K-12 teaching and learning with the most current theories of impacting and building successful learning designs for children with learning disabilities, at-risk, and all others. To do this we ask the following questions:

- How might barriers observed in Year 1 be addressed to facilitate success??
- What are opportunities for new interventions, strategies and possible relationships between professional development and positive change in the classroom?

Progress toward outcomes in Year 2 includes several steps related to research design, and communication and dissemination.

5.1 Research Design

- Revisit research questions and review observed barriers documented in Year 1.
- Scale our sample - narrow and focus on students with learning disabilities and/or at-risk for academic failure.

- Continue commitment to data-collection through student observation as the main goal in Year 2, but broaden this to include artifact analysis interviews and exploration ofC-COI and/or video capture.
- Schedule and conduct pilot studies in three 8th grade classrooms.
- Develop preliminary identification of which metacognitive strategies support student achievement in classroom-based maker activities, and how those strategies can be adopted by teachers.
- Refine instruments that will help to measure metacognitive strategies and how student engagement and learning can be measured.
- Observe how instruction that supports metacognitive strategies can be integrated within typical K-12 classroom makerspace activities to address barriers.

5.2 Communication and Dissemination

- Publish a website with curricula and strategies, alongside other resources associated with our project, such as research briefs that describe our work in progress and provide sample data collection instruments.
- Draft two papers based on the manuscript developed in Year 1: one to be presented at the annual meeting of the Council of Exceptional Children (https://cecconvention.org/), and one to be presented at the annual meeting of FabLearn (http://fablearn.org/conferences);
- Plan future professional development for those interested in accessible middle school makerspaces for diverse learners, based on MAPLE experiences and CU Fab Lab expertise for bringing accessible and engaging makerspace instruction to broad audiences.