Preview of Award 1721236 - Final Project Report

Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1721236
Project Title:	Project MAPLE: MAkerspaces Promoting Learning and Engagement
PD/PI Name:	Lisa A Bievenue, Principal Investigator Maya Israel, Co-Principal Investigator
Recipient Organization:	University of Illinois at Urbana-Champaign
Project/Grant Period:	09/01/2017 - 08/31/2021
Reporting Period:	09/01/2020 - 08/31/2021
Submitting Official (if other than PD\PI):	Lisa A Bievenue Principal Investigator
Submission Date:	12/19/2021
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Lisa A Bievenue

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Accomplishments

*** 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. It seeks to address the following research questions: (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).

*** What was accomplished under these goals and objectives (you must provide information for at least one of the 4 categories below)?**

Major Activities:

Literature Review

In years 1 and 2 (2017-2018) Project MAPLE completed a thorough review of literature relevant to makerspaces in schools, focusing on students with learning disabilities and at risk for academic failure.

Instrument Development

The following instruments were developed, piloted and utilized for data collection.

1. Classroom and activity observation rubric
2. Curriculum and artifact analysis based interview guide
3. Teacher interview guide
4. Student survey to assess engagement
5. Student focus group protocol
6. Teacher focus group protocol

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. Several instruments and two coding schema (one for teacher data, one for student data) are available as a product in this report.

Observations and Data Collection

Data collection was focused on observing and defining evidence of specific metacognitive strategies related to persistence, iteration, and intentionality. Additionally, evidence of levels of engagement and non-engagement were collected to further inform and define the context of barriers and learning.

Observations were initially conducted in three STEM lab classrooms and one Science classroom. These observations were the basis for development and refinement of the data collection instruments. Final data collection (years 2 and 3) was limited to one STEM lab classroom and the Science classroom for two major reasons: (1) observational access to specific students with learning disabilities and at risk for academic failure and (2) the teachers in the other two STEM classrooms experienced role changes and ultimately ended up leaving their positions before the conclusion of data collection. To help compensate for this loss of student access an additional after-school homework help and STEM lab data collection site was added. In addition to giving more access to at-risk students this site allowed our team to control several barriers to engagement identified in Year 1, allowing us to more directly compare learning experiences and outcomes as well as focus more on metacognitive processes.

One key finding regarding the data collection methods for observations was that embedded technology for observation was not effective at identifying and discovering metacognitive strategies being used. The student observation protocol was initially assessed with the use of simultaneous screen capture in mind, with the intent to use the Collaborative Computing Observation Instrument (C-COI) previously developed by Israel, et al. (2016). The team focused more on creating an effective direct student observation rubric that would identify the presence of specific metacognitive strategies. This search for specific strategies, however, was found to interfere with overall documentation of the student process and was discarded early in the process.

Assignments as designed often did not typically present or facilitate opportunities for observation of intentionality or iteration so our team chose to investigate these through interviews instead. It was concluded that it would be more informative to record as many descriptive notes as possible for later contextualized analysis. In addition, because the observable metacognition was so sparse, the team began to focus on levels of engagement, including a differentiation of passive vs. active engagement, as well as passive vs. active disengagement. Once we could identify instances of various levels of engagement we could also align that with type of activity, associated supports or curricular scaffolding, the level of engagement among nearby students, and teacher intervention.

Teacher surveys were administered at one of the sites in Year 2, to one of the participating teachers, and other teachers of the target students in that school. The survey targeted the teachers' perceptions of each student's attitude and achievement, engagement and participation in their classroom, the student's problem-solving strategies, the student's motivation, the teacher-student relationship, and direct rating of the student's persistence, iteration, and intentionality. The purpose of this survey used only at this school (where the majority of the Year 2 observation took place) was to compare the student's engagement, motivation and use of metacognitive strategies in their core classes (math, reading, writing, social studies, science) with their non-core STEM lab.

Analysis

Initially analysis focused on identifying systemic, pedagogical, and student-level barriers encountered by struggling learners during makerspace activities. In Year 2 analysis shifted to grappling more directly with refining accuracy and effectiveness of data-collection instruments with increased emphasis on establishing validity through iteration and cross-comparison. The need for more targeted and robust data drove us to seek it in new ways; our team reworked the instruments to more appropriately work with the teachers, kids and assignments and restructured the coding guide a number of times to better match what we saw and in correspondence with our evolving definition of variables tied to metacognition. By the end of Year 2 and into Year 3, data collection instruments worked smoothly and yielded data that could be reliably analyzed to determine preliminary findings.

Coding of student data began mid-way through Year 2 as an exploration of what types of evidence (indicators, connections, predictors) of use of metacognitive strategies (persistence, iteration, intentionality) we might be able to observe. Early analysis suggested that such evidence was sparse. The team struggled to look for ways to determine whether the strategies were not being observed because the strategies were not being used, or because the observation notes were insufficient, or because our definition and operationalization of the strategies was inaccurate. Senior research team members joined the classroom observation team and all observers began taking more detailed notes. In addition screen capture, with audio, was used to enhance the detail and completeness. This enabled the team to identify more instances of use of the target metacognitive strategies, but it was still an infrequent occurrence. Engagement was added as an observation goal, mainly as a result of the realization that if students are not engaged observation of any cognitive strategy was unlikely, and also because even minimal engagement is often a sign of persistence for struggling learners.

The shift to capture data on engagement led to an expanded coding guide. The research team iterated on the coding guide several times, reviewing and coding data, modifying protocols, refining the guide, reviewing and coding more data, and refining the guide again. By the end of Year 2 the team produced a clear and concise coding guide that included engagement, accompanying terminology guide, and has collaborated in the effort to code, cross-code, and triangulate data to ensure reliability.

This coding guide was used to analyze the student observation, survey, and interview data. All data was reviewed by a minimum of two research team members.

Israel, M., Wherfel, Q.M., Shehab, S., Ramos, E.A., Metzger, A., & Reese, G.C. (2016) Assessing collaborative computing: development of the Collaborative-Computing Observation Instrument (C-COI), Computer Science Education, 26:2-3, 208-233, DOI: 10.1080/08993408.2016.1231784

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 was important to work with models of makerspace curriculum that were both accessible and comparable, so our study could yield results to inform a variety of school settings. A major objective throughout this study was to fit makerspace learning experiences into existing teacher-identified curricular needs and STEM subject areas identified in collaboration with our partner schools. Throughout all periods of study design and data collection, we ensured that teacher objectives and interests, capacities and goals informed activities.

Instrument Development and Adaptation
Multiple instruments were used to measure pertinent metacognitive processes. Instruments included student observation protocols, teacher observation protocols, screen capture protocol, a teacher interview protocol, and an artifact-based interview protocol. Persistence (attitudes about making) and iteration (productive struggle) were observable through student observation (both direct observation and screen capture) and artifact interviews. Intentionality (planing with incremental steps) was difficult to observe, but was somewhat observable through student interviews and artifacts (e.g., worksheets and written descriptions of projects).

Observations and Pilot Study
In pre-pilot activities (Year 1) more than 50 classroom observations were 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 document and measure target metacognitive strategies. We cultivated initial support structures, such as co-constructed makerspace activities, and accompanying strategies to facilitate increased engagement and learning for students at risk for academic failure. We then piloted the implementation of these metacognitive strategies to iteratively refine them throughout Year 2. We also adjusted objectives slightly, as well as our timeline. In line with our original plan to collect data in Year 2, we committed to student observation as the main goal, with less of a focus on teacher and classroom observation. Notes were still kept on teacher interventions and interactions with students, but the main focus was on how the teacher interacted with the student being observed. During Year 2 we narrowed the scale of our sample and focused on students with learning disabilities and/or at risk for academic failure. The timeline of observations was slightly changed in that we started with minimal observations while the teachers were adjusting their curriculum and adapting to new strategies they had learned during the professional development and pushed back the full pilot and student observation schedule to the middle and end of the school year. Project staff worked with the teachers to implement activities that would improve the possibility of the research team being able to observe the target metacognitive strategies. For example, we strongly encouraged the teachers to incorporate pathways for iteration and student choice into their assignment requirements.

At the end of Year 2, there were sufficient rounds of data collection and analysis that it allowed us to address the project-related research questions about the relationship of strategies that support metacognitive learning within school-based makerspace activities. These progressive observations and studies resulted in a tested set of metacognitive strategies and support materials for implementing making experiences for struggling learners.

In summary, the types of data collected and analyzed include:

- Transcriptions of classroom observations of students,
- Transcriptions of student interviews
- Transcriptions of student focus groups
- Photovoice artifacts
- Screen capture video
- Artifacts (projects and worksheets)
- Student grades
- Teacher surveys

Artifacts, screen capture video, student interviews, and observations were aligned by student and date in order to create a comprehensive snapshot, as well as progression, of a particular student's work. This aligned representation of the student's work was then used to refine and calibrate a coding framework to be used across all data, a framework that is available for future study in this area as well.

Communication and Dissemination
Dissemination efforts have included:

- Preliminary research findings and sharing of data collection methodology via conference presentations.
- 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.
- Research findings via presentations and publications in peer-reviewed practitioner and research journals.

Other dissemination efforts still planned include:

- Website sharing data collection instruments, coding manuals, and other resources associated with our project. (This information has been prepared for dissemination and is simply awaiting the technical effort of creating the website.)

Data Analysis

Multiple instruments have been used to measure pertinent metacognitive processes including persistence (attitudes about making), iteration (productive struggle) and intentionality (plan with incremental steps). Instruments include student observation protocols, teacher observation protocols, a teacher interview protocol, and an artifact-based interview protocol.

A summary of data and coding:

- 25 subjects with proper consent
- 24 subjects interviewed
- 22 subjects with artifacts for analysis
- 10 subjects with grade reports from all classes during quarter observed
- 13 subjects observed at least 5 times, 6 at least 3 times, 6 at least once
- 14 subjects with observations coded at least three times by at least two coders, all subjects' observations coded at least once by one coder
- 15 subjects within the target population of LD, ELL, or at-risk, 14 with observations coded at least three times by at least two coders
- 20 subjects with summary analyses at draft stage (awaiting additional coding)
- 6 teacher observations
- 6 teacher interviews
- 10 surveys from other teachers (math, science, language arts, social studies) of 10 subjects
- 2 student focus groups

Significant Results:

Overall, our findings highlighted several barriers to effective student-centered learning in school-based makerspace activities and classrooms. Barriers can be categorized as

- **student barriers** -- performance task avoidance and limited persistence,
- **teacher barriers** -- unprepared to implement instructional strategies such as modeling, scaffolding and prompting to meet the needs of students with disabilities or at-risk, and
- **current practices in school barriers** -- limited access to STEM for students with disabilities, technology failure, limited instructional time, and limited professional development.

Student barriers

The students rarely tried these activities on their own. One teacher explained that her struggling learners, especially those with disabilities, often exhibited learned helplessness, wherein they would not initiate or persist in learning activities independently. Another teacher stated that students with disabilities feared failure in his class and exhibited limited persistence. The students' fear of failure often meant that he had to work one-on-one with them to help them maintain effort and persistence. Classroom observations also showcased task avoidance. The students with disabilities were often observed exhibiting off-task behaviors (i.e., making noise, using phone, chasing one another) as compared to their peers who were also talking with their peers, but were doing so while also working on their projects. Teachers usually attempted to re-engage the students by verbally or physically intervening to redirect them. However, given the teacher and student ratio, it is challenging for teachers to re-engage all the students.

Teacher barriers

The classroom observations showed that it was too challenging for teachers to implement instructional strategies (e.g., explicit instruction, modeling, prompting) to meet the needs of students with disabilities or at-risk in maker activities. One teacher prepared directions for every class including the agenda on the smartboard, worksheets, and verbal directions. However, she was not seen providing any form of cues to the students to look at those directions, which often resulted in students asking the same question repeatedly. Similarly, during another teacher's project field note reflections indicated that instruction seemed to have been given too quickly for students to grasp the necessary steps. Most interactions appear to be depositing of information to the student instead of prompting techniques to determine how to figure out the solution. Another teacher had a student with a learning disability whose IEP accommodations included reduced reading load and additional time to complete assignments. Despite these mandated accommodations, observers noted that the teacher did not give any relevant accommodations or instructions.

Current practices in school barriers

Limited Access to STEM for Students with LD

The number of students with disabilities was fewer than expected in all four classes observed. Although some students with learning disabilities, or ELL, or at-risk, were included, there were no students with intellectual disabilities, behavior disorders, or other more moderate to severe disabilities. One teacher noted that most students with intellectual and developmental disabilities were “pulled out” of the STEM course to receive reading recovery instruction (or other specialized interventions) and did not have an opportunity to participate in the STEM class. Thus, although there were a few students with disabilities in the STEM classes, the teachers did not have many experiences teaching students with disabilities in their classrooms. Another teacher, however, had an opposite experience in which she had more struggling learners in her class because most high-achieving students enrolled in courses such as foreign language or band. She reported that, “[A]s you’ve seen, we have some behavioral issue kids that are in there...I get one or two that are higher level and then most of them are not. They’re the ones who are struggling.” However, her class also did not include students with more significant needs.

Technology Failure

Across observations and interviews, teachers experienced technology challenges during maker activities. These challenges fell into four categories: (1) Technology failure, (2) lengthy bootup time, (3) internet stability issues, and (4) challenges associated with logging into systems such as Google classroom. For example, one teacher has a 3D printer in her classroom but the 3D printer did not always work reliably. Furthermore, some schools have used Chromebooks or PCs that have some internet connection issues and students constantly struggle to log-in, often mistyping or forgetting their login or password. As instructional time was limited (classes are only 40 minutes long), the technology challenges were viewed by teachers as problematic for implementation of the making activities.

Limited Instructional Time

Across four schools, a project usually took a week and each session lasted approximately 40 minutes. Setting up and wrapping up activities often took at least 10 minutes which left only 30 minutes for the activities themselves. Due to this limited time, there was not always time for student exploration and iteration. Ms. Morgan, for example, reported difficulty in facilitating tinkering due to time constraints. Furthermore, researchers observed that learners who needed additional support only received this instruction when they asked for one-on-one help as teachers dealt with 20 or more students per class. For instance, Mr. David explained that he was trying to provide accommodations for students with disabilities, but it took a lot of time to revise materials and instructions. He said, “I think a lot of teachers will say they can’t do [accommodations for students with disabilities] because they just don’t have time and that’s unfortunate” (May 16, 2018).

Limited Professional Development

Three teachers mentioned that there were limited opportunities for PD on either maker activities or inclusive instructional strategies. All four teachers were interested in learning different kinds of hands-on maker activities, but at the time of this study, they had not had opportunities to participate in any makerrelated PD. During the interviews, researchers asked the teachers about their background and any PD that they received. One teacher reported, “No. There were no maker related activities or even things like STEM-based [professional development]” (May 16, 2018). Two teachers confided that they struggled executing new maker activities. One teacher reported that PD was not always presented in ways that teachers could easily apply new content into their classrooms. Similar to PD on maker activities, teachers did not report having opportunities to attend PD related to culturally responsive instructional strategies or inclusive instructional strategies.

One barrier we were able to somewhat address relates to limited pedagogical practices to address a broad range of learners in classrooms. Given the challenges faced by the teachers, the research team developed a new professional development framework to support inclusive maker K-12 classrooms by incorporating Universal Design for Learning principles. A primary contribution of our PD model to the literature is the addition of effective instructional and behavioral strategies to support diverse learners, specifically targeting students with disabilities and at-risk. We found it was essential to incorporate not only fluency in making but address learner variability in PD sessions. To do so, the current study suggested addressing specific instructional strategies (i.e., UDL, explicit instruction, culturally responsive teaching, accommodations) during PD. Further, embedded coaching encouraged implementation of different instructional strategies into lesson plans.

Key outcomes or Other achievements:

One key outcome is a framework to represent, identify, and measure metacognitive strategies used by and promoted by makerspace activities. This framework is represented by a set of data collection instruments with a codebook to aid in analysis of data:

- teacher/classroom observation rubric, interview protocols and a codebook for analyzing teacher-focused data.
- student observation rubric, interview protocols and a codebook for analyzing student-focused data.

These products are attached to this report.

A second outcome is a set of recommendations for implementing making experiences targeting development of metacognitive strategies (persistence and intentionality) specifically for struggling learners. This is in final stages of refinement and will be available via the project website: http://cucfablab.org/research-site/grants/project-maple/. A near final draft is attached in the Product section of this report.

*** 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. A 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). One teacher also participated in the 2019 Pathfinders Summer Institute and another presented in collaboration with a MAPLE RA at the 2019 National Science Teachers Association conference.

The research team was also able to participate in three conference-related professional development opportunities:

- National Science Teachers Association conference, St. Louis, MO, April, 2019.
- FabLearn 2020, which was originally scheduled for March, 2020, but held on-line in October, 2020.
- Council for Exceptional Children Conference, Portland, OR, October, 2020.

*** Have the results been disseminated to communities of interest? If so, please provide details.**

In addition to a website at http://cucfablab.org/research-site/grants/project-maple/ two reviewed papers were presented at FabLearn, 2020, and one at the 2020 Council for Exceptional Children:

Lee, C., Arnett, H., Samuel, N., Bievenue, L., Ginger, J., Israel, M. (2020). Towards an Inclusive Model of Makerspace Educator Professional Development: Implications for Students with Disabilities and At-Risk. FabLearn Conference, October 9-11, 2020, New York, NY.

Lee, C., Samuel, N., Israel, M., Arnett, H., Bievenue, L., Ginger, J., Perry, M. (2020). Understanding Instructional Challenges and Approaches to Including Middle School Students with Disabilities in Makerspace activities: A cross-case analysis. FabLearn Conference, October 9-11, 2020, New York, NY.

Lee, C., & Bentz, J. (2020). *Makerspace Professional Development Needs of Middle School Teachers: Implications for Including Students with Learning Disabilities*. Presentation with Q&A at the Council for Exceptional Children Conference, Portland, OR.

Products

Books

Book Chapters

Inventions

Journals or Juried Conference Papers
View all journal publications currently available in the NSF Public Access Repository for this award.

The results in the NSF Public Access Repository will include a comprehensive listing of all journal publications recorded to date that are associated with this award.

Lee, Chung eun and Arnett, Heather and Samuel, Noah and Bievenue, Lisa and Ginger, Jeffrey and Israel, Maya. (2020). Towards an Inclusive Model of Makerspace Educator Professional Development: Implications for Students with Disabilities and At-Risk. *ACM International Conference Proceeding Series: 9th Annual Conference on Maker Education: Making as Resistance and Resilience, FabLearn 2020*. . Status = Deposited in NSF-PAR doi:https://doi.org/10.1145/3386201.3386209 ; Federal Government's License = Acknowledged. (Completed by Bievenue, Lisa on 12/19/2021) Full text Citation details

Lee, Chung eun and Samuel, Noah and Israel, Maya and Arnett, Heather and Bievenue, Lisa and Ginger, Jeffrey and Perry, Michele. (2020). Understanding Instructional Challenges and Approaches to Including Middle School Students with Disabilities in Makerspace activities: A cross-case analysis. *FabLearn '20: Proceedings of the FabLearn 2020 - 9th Annual Conference on Maker Education*. . Status = Deposited in NSF-PAR doi:https://doi.org/10.1145/3386201.3386208 ; Federal Government's License = Acknowledged. (Completed by Bievenue, Lisa on 12/19/2021) Full text Citation details

Licenses

Other Conference Presentations / Papers

Lee, C., & Bentz, J. (2020). *Makerspace Professional Development Needs of Middle School Teachers: Implications for Including Students with Learning Disabilities.*. Council for Exceptional Children Conference. Portland, OR. Status = OTHER; Acknowledgement of Federal Support = Yes

Other Products

Other Publications

Lisa Bievenue and Heather Arnett (2021). *Implementing Making Experiences for Struggling Learners*. A paper to be submitted for publication: recommendations for effective implementation of maker-based learning activities in middle school. Status = OTHER; Acknowledgement of Federal Support = Yes

Patent Applications

Technologies or Techniques

Thesis/Dissertations

Websites or Other Internet Sites

Project MAPLE: MAkerspaces Promoting Learning and Engagement
http://cucfablab.org/research-site/grants/project-maple/

Project MAPLE website with links to resources for evaluating school-based makerspaces impact for students with learning disabilities and at-risk of academic failure.

Supporting Files

Filename	Description	Uploaded By	Uploaded On
Student Interview and Observations Protocols and Codebook.pdf	Student-focused research instruments and codebook	Lisa Bievenue	12/18/2021
Teacher Interview and Observation protocol and codebook.pdf	Teacher-focused research instruments and codebook	Lisa Bievenue	12/18/2021
Makerspace Student Survey.docx.pdf	Student survey	Lisa Bievenue	12/18/2021
MAPLE Recommendations.pdf	Paper to submitted for publication: Implementing Making Experiences for Struggling Learners	Lisa Bievenue	12/19/2021

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Bievenue, Lisa	PD/PI	1
Israel, Maya	Co PD/PI	0
Bentz, Johnell	Faculty	0

Name	Most Senior Project Role	Nearest Person Month Worked
Perry, Michele	Consultant	0

Full details of individuals who have worked on the project:

Lisa A Bievenue
Email: bievenue@illinois.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Final editing and publishing of research instruments, protocols, and codebooks. Finalize website and products to be disseminated.

Funding Support: None

Change in active other support: No

International Collaboration: No
International Travel: No

Maya Israel
Email: misrael@coe.ufl.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 0

Contribution to the Project: None

Funding Support: None

Change in active other support: No

International Collaboration: No
International Travel: No

Johnell Bentz
Email: jbentz@illinois.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 0

Contribution to the Project: Consultant for metacognition.

Funding Support: N/A

International Collaboration: No
International Travel: No

Michele Perry
Email: mperry@perryandassociates.net
Most Senior Project Role: Consultant
Nearest Person Month Worked: 0

Contribution to the Project: Evaluator

Funding Support: N/A

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Champaign Unit School District	School or School Systems	Champaign, IL
Urbana Middle School	School or School Systems	Urbana, IL

Full details of organizations that have been involved as partners:

Champaign Unit School District

Organization Type: School or School Systems
Organization Location: Champaign, IL

Partner's Contribution to the Project:
Facilities
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution:

Urbana Middle School

Organization Type: School or School Systems
Organization Location: Urbana, IL

Partner's Contribution to the Project:
Facilities
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution:

Were other collaborators or contacts involved? If so, please provide details.

NA

Impacts

What is the impact on the development of the principal discipline(s) of the project?

Despite an increased focus on maker education in K-12 settings, teachers have reported limited support to deliver such instruction, especially with students with learning disabilities or at-risk of academic failure. This case study examined instructional supports for teachers, including professional development and coaching focused on makerspace classroom activities, as well as structural conditions, the integration of metacognitive learning strategies, positive behavior supports, and Universal Design for Learning (UDL).

A primary contribution of our PD model to the literature is the addition of effective instructional and behavioral strategies to support diverse learners, specifically targeting students with disabilities and at-risk. While previous PD models highlighted the

problem-solving and design thinking in application
of projects (Paganelli et al., 2017; Peterson & Scharber, 2018), it might not be sufficient to support a range of diverse learners. To resolve this issue, it was essential to incorporate not only fluency in making but address learner variability in PD sessions. To do so, the current study suggested addressing specific instructional strategies (i.e., UDL, explicit instruction, culturally responsive teaching, accommodations) during PD. Further, embedded coaching encouraged implementation of different instructional strategies into lesson plans. Similar findings from Israel et al. (2018) found coaching in STEM K-12 classrooms to be effective in promoting inclusive classrooms; the current study reinforces coaching as a crucial support for teachers.

Israel, M., Ray, M. J., Maa, W. C., Jeong, G. K., Lee, C., Lash, T., & Do, V. (2018). School-embedded and districtwide coaching in K-8 computer science: Implications for including students with disabilities. Journal of Technology and Teacher Education, 26(3), 471-501.

Paganelli, A., Cribbs, J. D., Huang, X. S., Pereira, N., Huss, J., Chandler, W., & Paganelli, A. (2017). The makerspace experience and teacher professional development. Professional Development in Education, 43(2), 232-235.

What is the impact on other disciplines?
Nothing to report.

What is the impact on the development of human resources?
Nothing to report.

What was the impact on teaching and educational experiences?

Given the proliferation of makerspace experiences in K-12 education, there is a growing need to ensure accessibility for all learners, including those with disabilities and those at risk of academic failure. The limited research on these populations suggests that it is essential to examine how a broader range of learners participate in K-12 maker activities and any barriers that they face.

K-12 formal education in the United States has a history of applied, hands-on learning in instructional areas such as inquiry-based science (Salmon, Rossman, & Dipinto, 2012), industrial arts (Barba, 2015), and art and design (Bequette, & Bequette, 2012), but maker activities as viable areas of instruction are only emerging in K-12 education (Meyer, 2017).

The idealized maker movement typically has focused on cultivating individual creativity rather than on aesthetics or specific tools or resources (May & Clapp 2017), which has sparked the attention of K-12 educators. K-12 leaders interested in bringing making into schools have focused on the “maker mindset,” hoping to create opportunities that promote student empowerment and problem-solving (Meyer, 2017). Additionally, some educators suggested that making in K-12 can provide authentic learning experiences with emphasis on interest, identity, and learning-by-demand (Hsu, Baldwin, & Ching, 2017). These attributes – empowerment, problem-solving, and authentic learning – help to foster the 21st century skills of communication, collaboration, creativity, and critical thinking (Blackley, Rahmawati, Fitriani, Sheffield, & Koul, 2018; Peppler & Bender, 2013). Intentional educational makerspaces often aimed to “harness the same intellectual playground concept for the purpose of inspiring deeper learning through deeper questioning” (Kurti, Kurti, & Fleming, 2014, p. 8).

There is also the emerging need to understand how classroom implementation of making aligns with pedagogical theories of constructivism and constructionism, which are fundamental to the maker movement (Willett, 2017). These theories call for hands-on experiences driven by the learner and, as such, may conflict with some traditional structures of formal education (Willett, 2017). In many places, however, K-12 education is shifting toward more flexible implementations of standards and assessment that emphasize inquiry-based approaches to learning, which is more aligned with authentic, engaging, and personalized making (Meyer, 2017). This is consistent with Seymour’s (2018) finding that students with disabilities or at-risk performed better during hands-on maker activities. However, while the hands-on nature of an activity may positively impact academic success, degree of self-regulation - how students followed instructions given by the teachers, their focus on tasks, and other general conduct within the maker activity - such as performance avoidance and limited persistence, could negatively influence task performance.

Second, it was critical to provide students with disabilities or at risk with appropriate accommodations. Although our findings indicated that hands-on activities and more project-based opened the door for students with disabilities or at risk to new interactions, needs and opportunities, they may need more explicit instruction to participate in makerspace activities. For example, students with disabilities or at risk often exhibited learned helplessness (Causton-Theoharis, 2009), which impedes creativity and independent thought during hands-on projects. Finding the right level of support requires teachers to balance the amount of intervention or guidance that facilitates self-learning without discouraging learners.

Research on makerspace related curriculum and teacher interactions can help illuminate how to provide that balance between explicit instruction and open exploration while also encouraging students to use metacognitive strategies. For example, the development of mediated choices, scaffolding to promote persistence or goal-setting, and outlets for personal expression are cited as benefits of maker learning (Peppler & Bender, 2013), and these should be further explored with students with disabilities.

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What is the impact on physical resources that form infrastructure?
Nothing to report.

What is the impact on institutional resources that form infrastructure?
Nothing to report.

What is the impact on information resources that form infrastructure?
Nothing to report.

What is the impact on technology transfer?
Nothing to report.

What is the impact on society beyond science and technology?
Nothing to report.

What percentage of the award's budget was spent in a foreign country?
Nothing to report.

Changes/Problems

Changes in approach and reason for change
Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them
Nothing to report.

Changes that have a significant impact on expenditures
Nothing to report.

Significant changes in use or care of human subjects
Nothing to report.

Significant changes in use or care of vertebrate animals
Nothing to report.

Significant changes in use or care of biohazards
Nothing to report.

Change in primary performance site location
Nothing to report.