Scaffolding Pedagogical Change: Professional Development to Support Elementary Teachers in Implementing Mobile Maker Kits

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Abstract: The purpose of this paper is to describe findings from a study in which we investigated a gradual increase of responsibility model to scaffold a 1st and a 3rd grade teacher as they integrated interdisciplinary, standards-based Mobile Maker Kits into their classrooms over the course of an academic year. Qualitative discourse and multimodal analysis techniques were used to investigate teacher practices and beliefs related to the integration of the kits, which included lesson plans linking all activities and materials (e.g., picture books, craft materials, tablets, 3D printers, circuits and other electronic materials) to ELA, science, math, and social studies standards. Findings identify the affordances and constraints of a gradual increase of responsibility model for supporting teachers. We conclude by offering implications for supporting the integration of Making practices into P-12 classrooms.

Introduction

The Maker movement has introduced new forms of interaction, innovation, and creative thinking to millions of people all throughout the world. While advocates for Making argue that these practices, which involve utilizing new and existing technologies to design, build, and manufacture, could potentially change conceptualizations of learning and teaching, supports and structures for utilizing Making in schools and classrooms remain largely unexplored. As Halverson and Sheridan (2014) argue, "Understanding the relationship among activities, communities, and identities in the context of our institutional landscape is the current grand challenge, and the maker movement is central to new institutional perspectives on learning" (p. 501). In an effort to explore how the implementation of Maker practices for academic purposes, our study examines how a scaffolded, gradual increase in responsibility model can support or constrain teachers' abilities to integrate of standards-based Maker kits into their classrooms.

After grounding our work in theories of Making and teacher learning, we detail the context for our study, describe the design of the gradual increase in responsibility model, and explain methods for collecting and analyzing data. Then, we describe how a 1st grade and a 3rd grade teacher navigated the integration of interdisciplinary, standards-based Making activities into their existing curricula across a series of three lessons each (one facilitator-led, one co-led, and one teacher-led). We conclude by drawing on findings from our study to suggest potentially useful professional development practices for supporting the integration of Making into classrooms.

Theoretical Framework

The Maker community encompasses "the growing number of people who are engaged in the creative production of artifacts in their daily lives and who find physical and digital forums to share their processes and

products with others" (Halverson & Sheridan, 2014, p. 496). In classrooms, Making can also serve as a counter to many weaknesses of more traditional methods, such as lecture, which can lead to fragmentation of learning and student passivity (Jackson, Dukerich, & Hestenes, 2008). However, integrating Making into a classroom environment presents a complex set of challenges for teachers, who must navigate often contrasting disciplinary norms and practices, in addition to new interactional relationships with students. For instance, in order to encourage innovation, creative production, and experimentation through Making, teachers must take on new roles as facilitators and enablers of student learning (Schön, Ebner, & Kumar, 2014), which may require a fundamental reshaping of their teaching practices and identities.

As Guskey (2002) notes, veteran teachers do not easily "alter or discard" practices that they have developed over years in their classrooms (p. 387). However, when introducing a new pedagogical innovation, such as Mobile Maker Kits, intensive professional development involving close collaboration between teachers and facilitators can support the process of pedagogical change. Research on teacher learning (Darling-Hammond & Richardson, 2009) has identified several key features that can support these pedagogical transformations, including varied exposures to new content and pedagogies (Grossman, Wineburg, & Woolman, 2001; Yoon, Duncan, Lee, Scarloss, and Shapley, 2007), ongoing collaborative discussion to address emerging problems of practice (Cohen & Hill, 2001), and time to reflect and refine new practices (Clarke & Hollingsworth, 2002).

Multi-faceted teacher learning models, in which teachers and facilitators work together to research, discuss, and collaboratively construct plans for implementing new pedagogical innovations, allow for the development of new knowledge and practices across contexts (Darling-Hammond & McLaughlin, 1995; Poglinco & Bach, 2004). One of these multi-faceted frameworks, Collet's (2012) gradual increase of responsibility model for teacher learning, is an adaptation of Pearson and Gallagher's (1983) gradual release model for classroom instruction. Positioning "the teacher as an active constructor of knowledge" can allow "for appropriation of ideas through multiple interactions over time" (Collet, 2012, p. 44). In order to support the gradual increase in responsibility, the facilitator or coach models an instructional practice, then collaborates with the teacher to co-construct and co-lead instruction, and then makes recommendations and affirms teacher decisions to push teachers towards increased responsibility and independence.

Despite the espousal of potential benefits for classroom integration of Making (McKay, Banks, & Wallace, 2016), researchers have not yet documented the types of teacher scaffolds, supports, and professional development activities that are necessary for successful classroom implementation of activities that link Making, standards, and existing curricula. While there have been a number of professional development for school leaders and educators, Oliver (2016) suggests that these activities have traditionally focused on the standalone makerspace and often include overviews of fundraising ideas, discussions of makerspace equipment and material, and sessions designed to create plans for community engagement and informal learning. In order to address these gaps in the literature, our study draws upon existing research and theory in order to adapt and study a gradual increase of responsibility model for supporting teacher integration of Mobile Maker kits into the classroom. In the next sections, we describe the context for our work, the design of the gradual increase in responsibility model, and the methods used to collect and analyze empirical data.

Methods

Our partner for this work is a diverse, rural to suburban district in the Southern United States. Our pilot school, Creekside Elementary (all location and participant names are pseudonyms), serves a diverse population (59% White, 27% African American, 13% Hispanic, and 7% two or more races) of more than 800 students, 50% of whom receive free or reduced lunch. Two Creekside teachers, Ellen (1st grade) and Page (3rd grade), worked with the research team to develop the Maker kits and to each pilot three lessons designed for their grade-level and standards/topics that they identified as part of their curricula. Purposive sampling (Patton, 2002) was used to select the teachers based on three criteria: graduation from a shared graduate-level specialized education program, an expressed interest in interdisciplinary teaching and learning, and a commitment to serving in a mentoring role throughout the next two years of the project. Ellen has seven years of teaching experience in the early childhood grades, while Page has taught for five years in third and fourth grade.

Research Question

Our analysis addresses the following research question:
1. What are the affordances and constraints of a scaffolded, gradual release model to support teachers' integration of interdisciplinary, standards-based Making kits into their classrooms?

Gradual Increase of Responsibility Model

A gradual increase of responsibility model was used to support both Creekside teachers throughout the 2017-2018 school year. First, in order to learn more about classroom culture and teaching beliefs, members of the research team observed each classroom and met with Ellen and Page individually to discuss their standards, curricula, and prior experiences with Making. We also worked collaboratively to identify student learning preferences and to pinpoint lesson topics and supplemental texts. Then, we interviewed all students in each classroom to understand learning preferences and histories and to get more information about prior experiences with Making. All lessons were designed based on this information, as well as ongoing feedback from Ellen, Page, and their students.

The pilot lessons for both classrooms were completed in December 2017, with a member of the research team leading the lesson and Ellen and Page observing and assisting as needed. After this lesson, both teachers were asked to provide feedback and given an opportunity to debrief. Prior to the second lessons, which took place in February, each teacher discussed another topic of need and sat down with a member of the research team to review the lesson plan. The goal was to co-teach the second lesson, with the Creekside classroom teachers being more active participants in the Mobile Maker Kit lesson. By April, when the third lessons were conducted, both Ellen and Page were expected to take the primary role in leading the lesson, including informing students of the task and facilitating the making process, with the research team providing assistance as needed. The teachers met with the research team to prepare for the lesson and the lesson plan and materials were dropped off in advance. Please see Table 1 for an overview of lessons, intended teacher roles, topics and standard addressed.

Table 1. Gradual Increase in Responsibility Model Lesson Overview, Roles, and Standards Addressed

Lesson Number	Teacher and Grade	Intended Teacher Role	Lesson Topic	Standards Addressed
1	Ellen (1st)	Observation	Shadow and Light	**Science** **1.P.2A.2** Analyze and interpret data from observations to compare how light behaves when it shines on different materials. **ELA** **1.C.1.1** Explore and create meaning through conversation, drama, questioning, and story-telling.
	Page (3rd)		Simple Circuits and the American Revolution	**Social Studies** **3-3.3** Summarize the course of the American Revolution. **Science** **3-3.A.2** Develop and use models to describe the path of an electric current in a complete simple circuit as it accomplishes a task (such as lighting a bulb or making a sound)
2	Ellen (1st)	Co-Lead	Problem and Solution Scarcity	**ELA** **8.1** Read or listen closely to: identify the plot including problem and solution; and describe cause and effect relationships. **6.1** Retell the central idea and key details to summarize a text heard, read, or viewed. **Social Studies** **1-4.4** Explain the concept of scarcity and the way it forces individuals and families to

				make choices about which goods and services they can obtain.
	Page (3rd)		Population Distribution	**ELA** **3-RI.11.1** Identify problem and solution, description, and question and answer structures to locate information and gain meaning. **Social Studies** **3-1.3** Explain interactions between the people and the physical landscape of, including the effects on population distribution, patterns of migration, access to natural resources, and economic development.
3	Ellen (1st)	Lead	Conserving Earth's Natural Resources	**1.E.4B.2** Obtain and communicate information to explain ways natural resources can be conserved (such as reducing trash through reuse, recycling, or replanting trees). **ELA** **1.RI.10.1** Identify the Author's purpose – to explain, entertain, inform, or convince. **Media Art** **MA1-1.2** Use a variety of media technologies, techniques, and processes to communicate ideas
	Page (3rd)		The Changing Economy of a South State after the American Revolution	**Math** **3.MDA.3** Collect, organize, classify, and interpret data with multiple categories and draw a scaled picture graph and a scaled bar graph to represent the data. **Social Studies** **3-4.**1 Compare the economic conditions for various classes of people, including the elite, the middle class, the lower class, the independent farmers, and the enslaved and free African Americans. **ELA** **3-W.2.**1 Write informative/explanatory texts that: a. introduce a topic and group related information together; c. include illustrations to aid comprehension; d. develop the topic with facts, definitions, and details; h. develop a style and tone authentic to the purpose; and i. provide a concluding statement or section.

Data Collection and Analysis

Primary sources of data used in this analysis included: teacher and student interviews; video and audio recordings of Mobile Maker Kit lessons; pedagogical artifacts created for the lessons; and surveys measuring teachers' beliefs regarding technology integration, Maker activities, and interdisciplinary STEM instruction. For all three pilot lessons, the research team utilized stationary and mobile cameras, as well as audio recorders, to document each of the six Mobile Maker Kit lessons (three for each teacher). In order to understand the affordances and constraints of the gradual increase of responsibility model and how it impacted the implementation of the lessons, video and audio recordings were microanalyzed using the multimodal discourse analysis (MMDA) approach, which assumes that social interactions necessarily rely on forms of communication beyond language (Kress & van Leeuwen, 2001; Norris, 2004). This approach allowed researchers to understand how standards-based Maker activities were defined and negotiated by participants. Other qualitative data (e.g., interviews, video-taped

recordings, and artifacts created during the Mobile Maker Kit lessons) were analyzed using open coding to identify patterns across data sources and axial coding to coordinate and integrate categories and themes (Lincoln & Guba, 1985). In order to ensure the credibility of findings, we triangulated findings across multiple sources of data and performed member checks to ensure that we reflected upon and included participant voice.

Findings

Findings are organized into two sections: affordances and constraints. In the first section, we describe two primary affordances of using the gradual increase of responsibility model for supporting teachers' integration of standards-based Mobile Maker Kits into 1st and 3rd grade classrooms: (1) it supported the teachers in introducing collaborative, transdisciplinary design thinking to students, and (2) scaffolded the introduction of potentially unfamiliar pedagogical practices, such as teaching students to embrace failure. In the second section, we describe two constraints emerging from our analysis of data: (1) the collaboratively-designed but facilitator-led lessons failed to fully utilize teachers' knowledge of students and classroom culture, and (2) the model does not provide enough explicit training and support in the initial stages; it assumes teachers learn what they need through modeling and conferencing. In both sections, we draw on examples from Ellen and Page's classrooms.

Affordances of the Gradual Increase in Responsibility Model

Initial interviews with students and teachers revealed a need for projects and curricular initiatives that incorporated key STEM and design thinking skills. Ellen and Page noted that they spent less than two hours total per week on science and social studies topics due to standardized testing pressures and limited time for any content area other than English Language Arts and math. Further, when we questioned Claire, a 1st grade student, about any experiments she had ever done, she replied, "I don't know what that is."

So, the use of the Mobile Maker Kits represented a shift in practice for both the teachers and their students. The following example is drawn from the use of a Mobile Maker Kit in Page's 3rd grade class, which began with students' reading and discussion of a book about the Swamp Fox, a local Revolutionary War figure. Using a light bulb, copper tape, a battery, and an overlaid message, students were then asked to compose a secret message to communicate information to fellow patriots without the British knowing. As the exchange between Alice and Calvin reveals, circuit spy message creation required students to navigate multiple disciplinary (ELA, science, social studies, and engineering) practices, as well as experimentation and design thinking.

> Alice: So, that didn't work. This one goes on the long side and this goes on the short side.
> Calvin: They can't touch.
> Alice: Ok. So, it doesn't feel like there's really tape on this.
> Calvin: So, like this? What's that for? Fold here. (holds copper tape out for Alice).
> Alice: Is it working?
> Calvin: Look, it's glowing.
> Alice: It's glowing. It shows the other spies where the weapons are!
> Calvin: Maybe we should add a symbol on the map to hide where it is, like the Swamp Fox.

The use of the gradual increase in responsibility model allowed Page and Ellen to observe and grow increasingly familiar with how to support students' participation in collaborative creative production, transdisciplinary design thinking, and experimentation. As Ellen noted in relation to the second lesson, in which her students constructed an invention to solve a problem in their community, the Mobile Maker Kits allowed students to interact with content, ideas, and experimentation: "The students really worked to create something useful. Many students stayed on task with the purpose of the lesson, others drifted, but still created something that was important to them. The students were very proud and I enjoyed watching the students experiment with their ideas and problem solve."

Another affordance of the gradual increase model was that it introduced Ellen and Page to unfamiliar and potentially uncomfortable pedagogical practices, such as teaching students to embrace failure in the service of Making. During open-ended Making projects, there is a high likelihood that students will experience failure in order to advance a project, which is contradictory to more traditional forms of teaching and learning. Kurti, Kurti, and Fleming (2014) even discuss "failure" as one of the guiding principles of makerspaces and "simply the first or

second or third step toward success" (p. 10). In the following exchange from the circuit spy message creation lesson, two 3rd graders, Adam and Ezekiel, experience failure as they create their message.

> Adam: It's hard to do this.
> Ezekiel: Just go in here and grab it, I don't want to mess this up.
> Ezekiel: So, the British are here. Where's the other one?
> Adam: This right here, this could be where they are.
> Ezekiel: Look at this, it looks so terrible. I can't fit the tape in for the circuit.
> Adam: I think we have to start over.
> Page (walking over to boys): Oh my goodness, this looks great.
> Ezekiel: It looks terrible. Am I doing it right?
> Page: It looks great!
> Ashley: So, did you do one and you're doing one? So, you have your idea down. It doesn't have to be done, because this is just your draft, right? But it looks like you have a good idea. Should we try the next step?
> Adam: *Is that okay?*
> Ashley: Of course! So, what we're going to do is this, you're going to use this as a template to help you. It's called copper tape, so it's going to help the electricity move on the page.
> Adam: So, the copper is the thing that helps it light up?

Page's initial reaction was to tell the students, "It looks great," but Ashley's response represents a shift from more traditional schooled interactions to a collaborative navigation of failure and discord. Although Adam didn't feel successful in the initial crafting of the message, seeing his draft as a step in the process, rather than a product that needed to be perfected, supported him in creating his spy message circuit. Figure 1 details how Adam and Ezekiel drafted, revised, and utilized a template to create a circuit spy message.

Figure 1. Adam and Ezekiel Draft, Revise, and Utilize a Template to Create a Circuit Spy Message

Page was later able to utilize the technique of supporting students through failure during the third lesson. As students were creating their paper slides, she navigated a student dispute about the use of cash crops by pointing to the use of a rough draft as a step in the process, rather than the end result: "You just got to figure out what you want them to look like...Remember, you're doing the rough draft." This experience suggests that in order to get students to challenge, negotiate, and discard ideas in the process of Making, teachers and discord over efficiency and ease. As Page said in her interview, "As educators, we've put education in a box and the makerspace takes it out of the box. Especially with the kids because they learn by discovering and they internalize by discovering, not sitting at a desk listening to someone else."

Constraints of the Gradual Increase in Responsibility Model

Despite working collaboratively with both teachers throughout the design process, one primary constraint of the gradual increase in responsibility model is that it failed to take full advantage of Page and Ellen's knowledge of their students, particularly in relation to appropriate pacing, scaffolding, and use of materials. As Ellen noted in regards to the second lesson, "I believe the lesson was great, but it was a lot to be put into one day. I believe the

puppet shows may have gone better, if they had more time and were able to focus on one goal for the day. For example, the first day goal/object being to build the puppet and explore with the puppet and then the second day goal/object being to make and record the puppet show. I would love to help more in the next lesson!"

For the third lesson, which involved creating stickers to promote the conservation of natural resources, Ellen chose to break the lesson into two days by reading the book and brainstorming on the first day, and then designing the stickers on the second day. The following exchange reveals how she draws on a student's prior knowledge and discussion to reinforce vocabulary and content covered in the previous lesson:

Ellen: I love the words that you're using, too, like recycle, and reuse. And remember, natural resources were something of value that we get from the earth, right?
Paisley: Yes, ma'am.
Ellen: So, like, air. What else? What is something else we get from the earth?
Paisley: Water.
Ellen: Water and --
Paisley: We get trees.
Ellen: Yeah, the plants, right. Good, yeah. So that's kind of where we left off. So where should we pick up [laughter]?

It is apparent that Ellen's knowledge of her students allowed her to support them in ways the research team may not have been able to. She also discussed that it was useful to have the lesson plans in advance so she could pre-teach. She explained that, "The maker lessons had great ideas but they needed to be spread out. I like to use the mentor texts and allow them to have time to generate ideas days before they started making. That way, they really understand the standards and story elements and they don't get lost while making." While the gradual increase in responsibility model did not explicitly say to do this, Ellen knows her students and their learning needs; she altered the lesson to best accommodate them.

The second primary constraint of the gradual increase in responsibility model relates to the lack of explicit training for teachers during the introduction the Mobile Maker Kits. As discussed, the research team conferenced with Ellen and Page prior to implementing the lessons and both teachers had opportunities to observe and co-teach a lesson before leading one. When asked about the training they had received, the teachers explained that there had not been any formal professional development. Ellen said, "I met with Ashley and went over what the kits were and saw the lesson plan but we never actually learned how to best use a maker kit." While they were exposed to the Mobile Maker Kits through modeling and discussion, there was no formal training on the Maker movement, the benefits of standards-based kits, and the individual pieces of the lesson.

Additionally, while teachers were encouraged to revise and provide input on the lessons, they did not create their own lessons and instead utilized ones that were primarily by the research team. While they discussed how much they liked the materials and standards covered in the Mobile Maker Kits, Page identified a major drawback to this approach: "I am curious about how a teacher knows what components to add to a maker lesson and why. I would want a breakdown of each part and how it helps the kids." Page also explained some of the constraints of this professional development model, as she described the challenge of teaching someone else's lesson: "The lesson was awesome and my students enjoyed it but I wish we had the opportunity to sit and plan. I wasn't totally familiar with it because I hadn't written it, which made it a little weird to teach." She explained that her students had a very positive experience and said, "They really had a good time thinking through the process and implementing their idea. They're still talking about it now and the last lesson was two to three months ago."

Conclusions and Discussion

In this paper, we've demonstrated that the gradual increase of responsibility model offers both affordances and constraints for scaffolding teachers' use of standards-based Mobile Maker Kits. Our work offers significant implications for researchers and educators interested in designing Maker activities and the implementation of learning activities that blur the boundaries between in-school and out-of-school learning spaces. First, this study responds to the call for additional research focused on connections among Making, standards, assessments, and interactions to understand the role of Making in formal academic institutions (Halverson & Sheridan, 2014; Oliver, 2016). Further, for teacher leaders and other educators interested in integrating Making practices into academic

settings, this study suggests ways to support teachers as they aim to broaden participation in collaborative, transdisciplinary design thinking in their classrooms.

However, while our findings demonstrate that the gradual increase in responsibility model offers potential for supporting pedagogical change, there are a number of limitations. Ellen and Page's reflections on their experiences, as well as our analysis of the classroom interactions, reveal that teachers need explicit training and opportunities to recursively create and revise lessons with support from facilitators. In a process of continuous reflection and redesign, we are currently developing and testing flexible, incremental supports, including just-in-time coaching activities initiated by teachers, opportunities to engage in asynchronous and synchronous discussions with other educators using the Mobile Maker Kits, and incentives for teachers to design Mobile Maker Kit lessons to share with their colleagues. By providing additional supports for teachers to integrate Making into their classrooms, including formal professional development training and the creation of a virtual community, we aim to increase access to active learning experiences that encourage both students and teachers to make, collaborate, and innovate.

Acknowledgements

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