“Finding the Right Window Into What They’re Doing”: Assessment of Maker-based Learning Experiences Remotely

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Abstract

During the pandemic, teachers whose practice depends on maker-based learning have had the added challenge of translating their hands-on lessons for remote teaching. Yet with students making remotely, how can a teacher monitor the students’ progress, offer timely feedback, or infer what the students understood? In short, how are teachers assessing this work? Working with a learning community of teachers who center hands-on making in their instruction regardless of academic discipline, this study was conducted to examine how teachers are supporting and assessing maker-based learning. Our study draws on observational field notes taken during the community’s meetings, interviews with four focal teachers, and artifacts from the teachers’ maker projects. Taking a values-based assessment approach, our findings reveal interesting shifts in teaching practice. Specifically, teachers incorporated social-emotional goals into the activities they design and monitor, students documented their artifacts and process, and teachers adapted to using low-tech materials to ensure accessibility while engaging remote students in their learning goals. These findings imply that not only can remote maker-based experiences can influence the role of students as assessors and the tools and materials they use for making but also how these practices revealed in remote settings could inform in-person settings.

Keywords Makerspace · Assessment · Remote instruction · Hybrid instruction

It is an understatement to say that remote learning has presented many challenges for teachers. Getting accustomed to new technology platforms, tracking down missing students, and managing their own lives amidst national and global crises are just a few of the challenges teachers faced during the COVID-19 pandemic, which mentions nothing of their instructional practice. Despite a raging pandemic, teachers continued designing lessons, presenting and facilitating instruction, and maintaining appropriately challenging content while building relationships with students. Teachers whose practice depended on maker-based learning have had the added challenge of translating their hands-on lessons for remote teaching.

Maker-based learning is growing as a means of engaging students in creative, STEM-rich learning experiences (Hsu et al., 2017). As many schools have gone remote or hybrid

(a combination of face-to-face and online teaching) during the pandemic, teachers have maintained a commitment to engage students in maker-based learning, or hands-on learning that is student-driven and involves old and new technologies (Wardrip & Brahms 2015; Sanders et al., 2019).

While remote and hybrid settings present challenges for teachers’ instructional practice, this study focuses on assessment in remote maker-based learning experiences. Assessment in these experiences, even in the most ideal situations, has been noted as a challenge (Lin et al., 2020). Yet, assessment in these learning experiences, like in others, can be an important part of instructional practice. For example, formative assessment and feedback practices of an educator can be consequential to students’ learning and engagement in maker-based learning experiences (Hadad et al., 2020), such as how they deal with setbacks (Maltese et al., 2018).

In this paper, we present findings from a group of teachers within the same learning community who have remotely enacted maker-based learning experiences with their students beginning in March 2020. Our analysis draws on observational field notes taken during the community’s meetings, interviews with four focal teachers and artifacts

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from the teachers' maker projects. We share thematic findings on the goals and values teachers' hope to foster in and with students (what they assess), the ways they approach assessment for their activities (how they assess), and the instructional and curricular designs they employ for learning activities to meet their goals. We also discuss the shifts and adjustments teachers made with respect to their goals, learning activities, and assessment along the way.

While research for this project remains ongoing, these teachers' experiences suggest the move to remote learning revealed as many opportunities as it did challenges, providing implications for how to support classroom, hybrid, and online maker-based learning experiences. Moreover, this study reveals possible implications that can inform in-person maker-based learning as well.

Background on Maker-based Learning

While the research literature on maker education has been extensively reviewed elsewhere (see for example, Hsu et al., 2017; Mersand, 2020), there are a few relevant points that should be made. Although the definitions for making can vary, in general, making is an "emerging form of educational practice that involves the design, construction, testing, and revision of a wide variety of objects, using high and low technologies, and integrating a range of disciplines including art, science, engineering, and mathematics" (Bevan, 2017, p. 75).

As an emerging educational practice, making has expanded greatly across various settings, such as libraries (e.g., Chang et al., 2019; Cun et al., 2019), museums (e.g., Gutwill et al., 2015; Wardrip & Brahms, 2020), K-12 schools (e.g., Eriksson et al., 2018; Wardrip & Brahms, 2016), and afterschool settings (e.g., Barton et al., 2017; Bevan et al., 2017). Since 2014, when the Obama administration advocated for a Nation of Makers (White House, 2014), educational makerspaces have been growing in schools around the United States (Kim et al., 2018). Similarly, across the world, maker-based learning and makerspaces have been growing in schools and other educational institutions (e.g., Rayna & Striukova, 2020; Vuorikari et al., 2019; Xi et al., 2017).

Maker-based learning has expanded in schools, but it has not happened without critique. For example, educational makerspaces have been criticized for serving mostly white, affluent, and male learners (e.g., Brahms & Crowley, 2016). Moreover, because of the costs of many common makerspace tools and equipment, some have suggested that makerspaces reinforce inequities that exist in schools (Hughes & Morrison, 2018). In general, makerspaces in schools may narrow what counts as making and not legitimize historical or cultural forms of building, creativity, and/or inquiry (Vossoughi et al., 2016).

Despite general consensus around what maker-based learning is and why it is important, there is a lot of diversity among maker-based programming. This diversity manifests in the materials and tools that learners use, the grade-levels that are engaged, and the content areas in which making is enacted. Even the motivations that drive the implementation of making in school districts differ. One district might view making as a means for building interest and agency in students (Dorph & Cannady, 2014), while another might see making as an entry point for engagement in STEM learning (Bevan, 2017).

Assessment of Learning in Making

Assessment is integral to good instruction (Shepard, 2000). Assessment in making in educational settings has been noted to be a challenge (e.g., Lin et al., 2020). This can be attributed to a variety of reasons, such as the heterogeneity of goals that guide teachers (Wardrip & Ryoo, 2020), the fact that students often make different products in their projects (Peppler & Keune, 2019), the intention of not interrupting the learner's experience (Murai et al., 2020), and the pragmatic limits in teachers' instructional practice. It can be challenging to enact assessment practices that align practically and epistemologically with learning experiences that are active and physical, like making (Gillies & Boyle, 2011).

Current research on assessment work in makerspaces has taken many forms. In their review of literature on technology-rich maker activities, Lin et al. (2020) noted that five types of assessment tools have been prevalent in other studies: artifact assessments, tests, surveys, interviews, and observations. In more analog-focused settings, observation tools and practices have been employed to identify evidence of learning (e.g., Gutwill et al., 2015; Kumar et al., 2019; Martin et al., 2020) as well as embedded strategies, like rubrics (Murai et al., 2020). Similarly, Sanders et al. (2019) emphasized the role of student collaboration and feedback within their Maker's Workshop framework to embed feedback and reflection in the learning process.

Additionally, assessment can be a useful way to understand the kind of learning experiences people have when engaged in maker-based programming. As an example, assessment in maker-based education can be supported through more detailed documentation of learning, especially when these experiences go remote or hybrid. Studying assessment tools and practices can also reveal the intentions of the teacher, what they consider success in a task or project, and the expectations they have for the students (Wiggins, 1998). Such attention to their own practices can help teachers revise their curriculum and pedagogy. In this paper, we specifically use the teachers' assessment strategies as the entry point of our inquiry.

Conceptual Framework

To engage in our inquiry, we took a values-based perspective on assessment (Wardrip, et al, 2018). This perspective is a framework for assessment and for guiding professional learning, where teachers' curricular and instructional designs are guided by what they think is important for the learners they work with. Values-based assessment first works from the assumption that assessment serves as an evidentiary argument about learning and understanding given a learners' behavior in certain situations (Gorin, 2014). The evidence that teachers are able to gather about student learning and engagement allows them to make inferences about what students can do.

This perspective takes what a teacher values for student learning and engagement as a starting point and as the targets for assessment. Teachers' values account for the desired outcomes that they have for students, ensuring those desired outcomes are a key consideration in educational measurement (McTighe, 2018). In maker-based learning, this values-based approach to assessment can be useful, because making can serve a variety of learning goals. For instance, putting together a circuit can show a student understands how to complete a circuit, but it can also show they are persistent in the face of challenges, that they are problem-solvers, collaborators, etc., depending on how the activity is designed.

Once the value or values are identified, the criteria, descriptors, and manifestations of those values are identified to discern what constitutes as evidence of engagement in the value. The criteria help suggest the sources of evidence necessary and inform the documentation process for assessment. For example, a student who can complete a circuit in a maker activity could take a photo or video of the completed circuit, take apart a circuit and label the components, or build an animation of how a circuit works. Finally, once the value is identified and defined, the teacher then can begin to design learning activities that elicit evidence of engagement in the desired value. This is similar to evidence-centered design in that the activity design is motivated by the generation of specific types of evidence of a construct (Mislevy et al., 2003).

The values-based perspective on assessment gives us an opportunity to explore both assessment practices in remote maker-based learning experiences and teachers' perceptions on the value of assessment and its relationship to learning. From this perspective, we focus our attention analytically on how teachers talk about their learning goals (their values), what constitutes evidence of engagement in the value (how do teachers monitor and attend to student learning and engagement for assessment), and how teachers design for their value (how teachers link the activity to their value).

Methods

The overall research question that guided this inquiry was: What does assessment look like in remote, maker-based learning activities? We also identified three sub-questions that could help us answer the overarching research question:

- What do teachers value for student learning and engagement and, thus, what do they assess?
- What constitutes evidence of engagement in the value, or how are teachers assessing?
- How do teachers design for their value and for assessment?

Setting and Participants

We drew upon data from teachers who are part of a teacher learning community in Western Pennsylvania called Agency by Design Pittsburgh (AbD PGH). AbD PGH, as a teacher learning community, was started six years ago and is an off-shoot of a program of work called Agency by Design (Clapp et al., 2016). Teachers interested in student agency and assessment in maker-based learning are invited to participate in the community. The community includes teachers from schools and out-of-school learning organizations serving a variety of grade levels and content areas. At the beginning of a school year, the teachers identify a value—what they want to see for student learning and engagement in their setting. Over the course of the year, they identify and refine what constitutes evidence of engagement in their value through sharing documentation with other teachers in the community and designing new activities. In a typical year, the community of 30 teachers meets once a month for a full day to share documentation of student learning, lesson artifacts, and engage in maker activities as learners themselves.

During the pandemic, the community was smaller, just 15 teachers, and the online meetings were shorter. Despite its reduced size, the community of teachers continued to meet voluntarily and work collectively to further their own instructional practice around making. All of the teachers have experienced some level of remote instruction in the past year. Apart from two teachers, all the teachers had taught face to face at various points throughout the school year. However, even the face-to-face teaching had to be hybrid due to some students opting out of in-person instruction, student illness, or students' need to quarantine.

As we discuss in the following section on data collection, most of our analysis draws on interviews with four focal teachers (of the 15) who had been members of the teacher learning community for at least a year prior to the pandemic were practiced at identifying a value to guide their

assessment and activity design. The teachers were chosen using purposive sampling based on several criteria. First, we selected these teachers based on their experience facilitating remote, maker-based learning experiences. Second, these teachers worked in similar classes and age groups; the focal teachers taught STEAM classes in primary school grades. It is also worth mentioning that these teachers' classes were "specials," which meant they did not meet every day. Finally, through our relationship with these teachers from the previous year, we knew they would be eager to discuss their assessment perspectives and practices. Table 1

Data Collection

This study draws from three primary sources of data: field notes, interviews, and documentation of student work. First, observational field notes were taken during the six online community meetings during the school year. On average, 12 teachers participated in each meeting. The field notes captured topics that were discussed during the meetings from all of the participants, such as the remote maker activities they were facilitating, how they were assessing what students were learning, and challenges they were facing. Second, four focal teachers were interviewed. These interviews were semi-structured, lasted between 30–60 min, and were conducted and recorded via Zoom. Third, documentation from the teachers' practice served as concrete examples of what the students actually did. These artifacts included 31 videos and photos of student work from the focal teachers as well as four class newsletters from another participating teacher. We used at least seven artifacts from each focal teacher.

Data Analysis

After each of the interviews was conducted, two of the researchers discussed emerging impressions from the interviews, how those impressions related to larger themes within the community, and possible explanations for those themes. This process occurred by comparing notes taken during the interviews with observation notes taken during the community meetings and through memo writing about those conversations (Maxwell, 2013). The Zoom recordings of the interviews were transcribed through the automated

transcription service, Trint, and then cleaned up by one of the researchers. This cleaning of the transcripts also initiated analyses and provided concrete examples of high-level themes (i.e. the three sub-questions guiding this study) that could be included into the researchers' analytic discussions (Bird, 2005).

Because the analysis was guided by the three sub-questions derived from the values-based assessment perspective (mentioned above), the team engaged in structural coding of the data using those questions to identify additional examples of the high-level themes (Saldaña, 2015). Specifically, one member of the research team engaged in coding. The process of structural coding led to the identification of sub-codes, or secondary themes. These sub-codes either fit under the umbrella of a sub-question or became their own "parent" codes that were relevant to the sub-questions but distinct. The final process of pattern coding allowed for further "lumping" of data into themes (Saldaña, 2015).

Throughout the coding cycles, the research team continued to meet, and discussed alternative explanations or interpretations of the data (Maxwell, 2013; Merriam & Tisdell, 2016). The team engaged in constant comparison of the data (Corbin & Strauss, 2008), whereby one researcher, who conducted the interviews and was most familiar with the interview notes and lesson artifacts, compared their interpretation of the data with another, who cleaned and coded the interview transcriptions. Afterward, the findings were shared with a third research member, who co-facilitated the community meetings, and the learning community in order to check the analyses and ensure the validity of the researchers' inferences (Maxwell, 2013).

We attempted to maintain credibility in our analysis in several ways (Lincoln & Guba, 1985). First, we maintained methodological consistency throughout our data collection and analysis (Morse et al., 2002). That is to say, our data and analysis were aligned with our research question, sub-questions and conceptual framework. This alignment was not intended to constrain our analytic process but to ensure a "trustworthiness" (Lincoln, 1995) so that our point of inquiry, analytic approach, and analysis were done systematically and as intended. Second, we maintained regular open and critical discussions of our analysis among the researchers. The data analysis process and findings were

Table 1 Focal Teachers

Focal Teachers (pseudonyms)	Class Taught	Grade Levels	Values-focus of the Teachers
Ramona	STEAM	Kindergarten – 5 th Grade	Perseverance
Charlie	STEAM	2 nd – 4 th Grade	Meaningful Connections
Martina	STEAM	Kindergarten – 2 nd Grade	Creative Problem Solving
Amal	Computational Thinking & Computer Science	Kindergarten – 5 th Grade	Differentiation

refined until consensus was reached. Our consensus building process was developed through triangulation with the three research members, the research members and the community of teachers, and the variety of data sources, which allowed for a third opportunity to increase the credibility of the analysis (Merriam & Tisdell, 2016).

Findings

To answer our overarching question (i.e., What does assessment look like in remote, maker-based learning activities?), we present our findings by the three sub-questions driving this work.

What do teachers assess?

Some of the teachers started this year with the same value or learning goal at the center of their practice as their previous year of teaching. They identified values like intentionality and resilience, patience, perseverance, experiential learning, collaboration, and communication, adaptation, independent curiosity, and emotional and physical well-being. Of the teachers interviewed, Martina said she would be focusing on creative problem solving, Amal on “differentiation” or the flexibility necessary for student agency and customized learning, Ramona planned to focus on perseverance, and Charlie on making “relevant, meaningful, relatable connections.”

When reflecting on the values they named at the beginning of the school year, the teachers acknowledged their values mostly stayed the same but that remote teaching led them to include another value or to view their value in a new light. For instance, Martina decided to focus on creative problem solving, saying she wanted to get students to “start thinking through a problem and not just following [her] sample.” It was also evident in her interview that students learning science content about outer space, the theme for her activity, was also important but more difficult to accomplish.

In addition to these goals, keeping students engaged and excited about learning was important. For example, when reflecting on whether to focus on content goals, such as engineering design, or getting students excited about the content, Martina said, “I feel like the excitement part is probably more of what I’m going for...I just think, like for this year, it’s more just like: can I keep them going and connected to this?” Martina’s reflection revealed yet another value for learning in which students were able to maintain excitement for learning when the pandemic made that particularly difficult. In showing concern for students developing a positive relationship to learning and schooling, she included a learning goal that focused on students’ socio-emotional well-being.

Other teachers’ values also were influenced by a concern with students’ socio-emotional well-being, which was put into sharp relief by the pandemic and remote learning. The value Ramona designed for in maker-based learning was persistence. However, she noted that this was difficult. While she was remote with students, she wanted to create opportunities through making where the students needed to persist in the face of difficulties. Yet, she said, she was treading lightly: “I know that a lot of my students are emotional—like where they’re at is just not great. So, you know, their threshold is not as great as it used to be, right? So, I’m not going to push them to be persistent when they’re, like, just totally done.” While her value was still relevant, she needed to be mindful of how she could appropriately challenge her students. As another teacher said during a community meeting, “Last year my value was perseverance, and that’s still relevant...but I want to focus on joy and engagement.” In short, the teachers have broadened their goals and thus what they need to assess and monitor.

How are teachers assessing?

While in a remote learning environment, teachers had to rely heavily on digital assessment strategies to gain insight into students’ thinking and making processes. Students recorded video of themselves, took pictures of their work, or recorded audio of their reflections and processes after making. Although the teachers had to adjust how they documented student learning, they did not fundamentally change the types of evidence they were looking for, the ways they looked for that evidence, or what constituted engagement in their value. Teachers still depended on observations, student reflections, and informal conversations with students to assess student learning.

For example, the teachers had students capture their artifacts and work on their artifacts. This included videos and photos of various student projects, such as the students’ chain reactions, space landers, origami boats, etc. Ramona had students share videos of their making process and looked at what students were doing in the videos to determine whether they were engaging in her chosen value of persisting. She looked for “those little moments of clarity when they fail or make a mistake. And then they come back to the camera and they say, you know, I tried to do this.” Other teachers in the community also found ways to document their students’ work digitally, relying on the video recording features of FlipGrid or the semi-permanent cloud storage of Google Classroom (educational and digital content sharing platforms). These features allowed teachers to continue “checking in” with their students’ progress, which they might have accomplished previously by silently scanning the classroom as students worked. Additionally, as teachers became more fluent in how to use digital technology to

document student work, they began to recognize which technology would best suit their assessment needs. For Charlie, the teacher who initially only used photos of the products, the photos were not sufficient to make sense of students' learning. As she put it, students could have unimpressive final products but put in a lot of work and thinking in their making process, a process which remained invisible through photos of final products alone.

In addition to the making process, the teachers encouraged students to provide explanations. Charlie eventually had students make informal, self-assessment videos answering reflection questions about the strengths and weaknesses of the project they were working on. They also considered questions about possible solutions they could apply in future iterations. To assess her value of students understanding and caring about what they were making, Charlie looked at their level of effort and their intentionality; she said she looked at their videos and asked, "Did they have a problem they were solving, or did they just make something pretty?... They had to say the problem and then say the solution (they developed)." The students' reflections on their making process not only allowed Charlie to understand their process but also how the students made sense of their process.

An unanticipated benefit of the student videos was that they created opportunities for student expression that might not have been evident if teachers had been working with students in person or simply scanning the room as they worked. Ramona said she learned about certain quirks in her students, such as the student who always recorded her videos with a teddy bear or the one who gave explanations about his making with an English accent. In this way, she discovered an opportunity to not only make assessments about what her students were engaging in but also express who they are. Similarly, Charlie said that she "really (got) to know the individual students better" than the previous year because she had digital documentation from all students. Before the pandemic, she said that she knew the outgoing students really well but not as well as the quiet ones. Amal further demonstrated this benefit when she noted that the student recordings showed "a lot of talent that I had never seen before," which was in contrast to when she relied exclusively on "walking around and watching" for in-person teaching.

Finally, the digital documentation created a repository of student work. Martina said she had students record short videos of explanations and reflections on Flipgrid. Even though she wanted to have students build portfolios for several years, she thought it would be too much work. Then, a couple months into the semester, it occurred to her that she already had portfolios in Flipgrid of all her students' work since moving to remote teaching. Ramona also acknowledged that having so many videos of students to build portfolios of their work and progress was a benefit of remote teaching. She said that the videos could serve "as documentation

for myself and for the future, for their future portfolios." Not only could a portfolio serve as a record of students' path through the school year but also for Ramona to reflect on her students' learning and her own teaching.

How do teachers design for their value and assessment?

The teachers stated that they implemented similar maker projects as they did pre-pandemic in the same way that they have maintained the same values or learning goals and assessment approaches. However, the teachers noted two interrelated changes to their projects. First, the projects were adapted to use materials that were low-tech, as in simple, basic, or found materials. Second, students were given more choice for the materials they used.

The shift to low-tech materials was partially due to cost restrictions and the feasibility of getting large numbers of maker materials to students at home, which is illustrated by Amal's quote:

Yeah, I mean I've always been the person that is all about the bigger and the better, going to the conferences, getting my \$500 drone. You know? I just like that. I like all of the technology. But what this really taught me is there's no way for a Title I District school to purchase expensive materials for their students to take home and use. Right now, there is not money in the budget, and after COVID, it might even be more difficult to afford.

As a result, she also adjusted her learning activities. Where she used to engage students in something she called Epic Challenges, she instead focused on small, simple tasks that anyone could do at home during the pandemic. Similarly, Charlie needed to adjust her materials based on cost. She said:

[I] taught the students origami because I was not allowed to do the boat challenge that I've always done, which is just random supplies plus foil. And foil is expensive. And I have to have individual students doing this and I have 800. They (students) could be here, they could be at home. So, I taught them the Origami Boat because we have a ton of paper.

Charlie noted the fiscal challenge of purchasing materials for all 800 students and highlighted that she was facilitating maker-based learning experiences for students both at home and in the classroom— a common occurrence for teachers we spoke with. With the change in materials, Charlie had to rethink her learning activity to meet her learning and engagement goals while also working within budget constraints.

The teachers' choices for materials were restricted by their budgets, but they also commented on the challenge of not being able to assume students would have similar materials at home. In planning her activities for what students might have access to, Amal said that this "kind of changed my whole mind with equity in making. I just assumed everybody had a scissors at home. That was a definite no." In many cases, the teachers could not plan on students all having access to the same materials, which was different from how they typically taught class with a selection of materials being made available to all of the students through the school.

Acknowledging that students had access to different materials and tools meant that the teachers sometimes had to relinquish control over the materials students used. Ramona designed and facilitated a chain reaction activity, sometimes referred to as a Rube Goldberg activity. In considering materials, she said, "We needed something that everybody could have at home. And that was pretty much the criteria." The prompt was: "Get a ball into a cup." In short, Ramona said that this activity, like others, needed to be adapted to what the students had. She said, "I plan these things that I know that they'll have, possibly anything, like the Rube Goldberg: find a cup, find a ball, make a ball (if you don't have one). Crumple up pieces of paper. You can do it. You know?" In showing flexibility for what can count as a ball, Ramona demonstrated an affordance of this type of activity in which students were able to be incredibly creative and innovative with their making. Additionally, by having students also pull together their own materials, Ramona created another opportunity for students to show engagement in her value of persistence. Another teacher from the larger learning community made a similar statement about the need for string in a project. If students did not have string at their house, they were encouraged to use shoelaces, dental floss, or something else that was not string but could serve the purpose of string.

Finally, in using inexpensive or found materials students had available, teachers recognized the value of low-tech materials in making. For example, Amal said that she and some of her colleagues were trying to "stay away from teaching the technology and instead teaching the skills." This perspective illustrates the connection between activity design and assessment. Having a particular skill that one values and wants their students to develop allowed teachers to focus on how the activity supported the skill development and less on how the technology fit into that process. Martina provided an example of how her focus on technology actually diverted attention away from making when she reflected on the role of technology in maker-based learning more broadly:

I feel like over the past couple years...like (with) different initiatives and stuff, I got away from a lot of the making and focused more on technology. And so now

that it's like not really any technology and all like the making, it feels a lot less daunting.

Martina's comment demonstrates how some of her previous maker activities might have been technology-focused and not necessarily focused on her priorities of making or her values.

Amal reflected on the role of technology in her practice moving forward: "I think making will be more prevalent because you don't have to buy a \$300 drone. If you're teaching a skill, problem solving, perseverance, you can use a tool like paper." Charlie, too, expressed that by emphasizing the process of making instead of the tools, her students are more "focused on the design." In fact, while she was at first disappointed that she would have to rethink her project because of the shift to low-tech materials, she eventually became excited: "[Students] could use their crayons, they could use tape...and glue. That was basically it. But I felt like that would really let them hone in on [the design]; it really helped them break it down. I'll probably do this again." Overall, despite the adjustments teachers made to accommodate the new restrictions of the pandemic in their maker activities, students were still able to continue developing the values they designed for and even benefited from making with basic tools.

Discussion

In seeking to understand what assessment looked like for teachers within the AbD PGH community during remote, maker-based learning, we encountered a great deal of pragmatic changes. These changes led to teachers' shifts in perspectives about (1) the relationship between socio-emotional goals and what they value for student learning and engagement, (2) the affordances of remote assessment particularly with regard to documentation, and (3) what it means to learn through making from an equity standpoint.

Teachers were forced to make curricular and instructional changes once schooling was thrust online. Some had to design entirely new activities students could engage in at home, while others had to rethink the materials students would use in their projects. Despite the challenge of translating hands-on maker activities to remote learning, the innovations in turn revealed some interesting opportunities for maker education. First, while the teachers noted that they maintained a focus on their values from before the pandemic, they also sought to address additional values, namely, social-emotional goals, such as joy and emotional well-being. Despite the unfortunate mental health toll that the pandemic has taken on our students, the fact that teachers sought to integrate social-emotional learning goals aligns with research on productive socio-emotional

implementation strategies (Jones et al., 2018). These include adapting designs to a local context to support the ownership of teachers and integrating the socio-emotional into the teachers' instructional practice.

With their assessment strategies, teachers needed to rely on videos and photos of students' work as well as explanations of their work. This creates several opportunities for consideration in post-pandemic maker education—both remote and face-to-face. First, the students had to be positioned as the documenters. Involving students in the process, including giving them control of what evidence is used to communicate what they can do, is one approach to making the assessment process more transparent and part of the learning process for students (Stiggins & Chappuis, 2005). This is more necessary in a remote setting since the students are dispersed in their own home settings. This student-involved assessment can also cultivate their capacity to provide feedback to one another (Sanders et al., 2019). In addition, having students document and talk about their work as a routine builds a repository of their making projects and processes. This repository could serve as a portfolio of their learning over the course of a semester or school year. While this holds potential for face-to-face settings as well, this is more important in remote settings where student documentation is the main way teachers see what students are making. While extensively written about elsewhere (e.g., Gardner, 1989; Keune et al., 2017), it is worth noting the video clips that students provided to explain their work mimics the format of popular media outlets, like YouTube. This similarity has been cited as a motivation for students to engage in the documentation and portfolio development process (Peppler & Keune, 2019).

The teachers discussed their approach to selecting materials for their maker-based activities. This included a significant shift toward what they considered “low tech” as well as shifting the choice for selecting materials to the students. These shifts have interesting implications moving forward for both remote and face-to-face maker education. First, while changes were primarily driven for practical reasons, they also revealed the persistent issue of equity in making (Barton et al., 2017). By using different materials, teachers were reminded of the critical importance of ensuring all students are able to construct meaningfully with available materials, even if that means abandoning the latest technology. For the teachers who, pre-pandemic, eagerly shared expensive technology with their students, this shift was extreme. They were forced to recognize how much families relied on schools for basic materials, like pencils and paper, which provoked introspection about the sufficient and necessary conditions for learning through making that would empower all their students to succeed at home. Further, the fact that teachers were able to accommodate accessibility needs with low-tech materials without weakening students' ability to

learn through making also implies that specific, expensive, or rare tools are not always necessary for learning through making. This insight implores maker educators to reflect deeply and honestly on whether a piece of technology is key to learning or whether it might add noise to the making process. This insight also reaffirms, to a small extent, the critique scholars have advanced around the fundamental inequity that emerges when maker education is associated with upper-class, male-dominated Silicon Valley and expensive tools or projects (Vossoughi et al., 2016).

Second, while making is often characterized as an interest-based or choice-based learning experience (e.g., Hsu et al., 2017), the changes to low-tech materials created more opportunities for students to exercise choice. As mentioned above, if a project required a ball, students could choose some material that is spherical or could be formed into that shape. This is in contrast to the control the teachers typically had over the materials students could use for a project. Instead of providing a table of materials for the students to choose from, the students were choosing from what was available in their world.

Third, the shift to low-tech materials also holds implications for assessment. The teachers' success with their students illustrates that low-tech activities can still facilitate engagement in teachers' predetermined values. In fact, in some cases, as the teachers adapted the materials for their students' accessibility, they were able to better clarify how their activity designs aligned with what they value for learning and engagement. As Charlie mentioned, de-emphasizing the importance of materials acted as a kind of “control” in students' making process. With paper as everyone's main tool, students had to really focus on how they designed their origami boats to hold weight. However, one might need to consider the prompt that launches the learner and how they build. This means viewing assessment as part of the activity design and not something that happens solely at the end of the project (Pellegrino et al., 2016; Sanders et al., 2019).

For the four AbD PGH teachers interviewed, remote, maker-based learning provoked anticipated practical changes as well as profound philosophical shifts. But equally profound were the few elements that did not change in the switch to remote learning. Despite the foundational innovations teachers made, they claimed to have focused on supporting the same learning values that were important to them pre-pandemic, only sometimes slightly redefining those values in the face of the pandemic or expanding their definition because of it. Specifically, teachers still facilitated familiar maker activities and did not abandon hands-on making even with the new challenges they encountered. They still used the same strategies for assessment even when their documentation process changed, continuing to rely on reflective conversations and observation, and they looked for the same kinds of evidence of learning (e.g., persisting

through a challenge) only this time through a screen. In other words, those pedagogical elements which remained the same for teachers revealed strong commitments to the particular importance of learning through hands-on making and the fundamental relationship between values for learning and values for assessment (McTighe, 2018).

Overall, our data suggest the teachers were focused on designing for and assessing the same values and learning goals that they did pre-pandemic; however, they additionally were designing and assessing for social-emotional constructs they deemed important based on the current state of the world. Our data also suggest the teachers were using some of the same assessment strategies of observation and giving students a chance to explain what they made, but these strategies were now mediated through a virtual format where students posted photographs and videos of themselves demonstrating and explaining what they made. Finally, our data show teachers were designing and assessing similar maker activities for their students remotely and making the most modifications with respect to materials, giving students opportunities to choose their materials and shifting to low-tech or inexpensive, non-digital materials.

These findings point to some implications for the future of remote, maker instruction. First, these teachers point to how digital and analog materials support instruction and assessment. While teachers' facility with online technologies are important, intentionally integrating the digital and the analog also may be a consequential part of their maker instructional practice. In addition, assessment of learning and engagement in remote maker instruction is multi-modal, which requires a variety of strategies to collect evidence. Like rigorous performance assessment in face-to-face environments, remote maker instruction has an array of tools and strategies to collect evidence of what students are doing and learning. The data from these teachers suggest that partnering with students in the assessment process may be a necessary strategy for remote maker instruction. And, finally, as demonstrated by all of these implications, we need to build and support the capacity of teachers to support their learners across digital and in-person settings.

In closing, it is also worth mentioning the potential of a values-based approach to teachers' practice in remote settings, as seen through this study. In open-ended, maker-based settings, teachers can have a variety of goals and motivations (Wardrip & Brahms, 2020). Identifying and discerning the evidence for what the teachers value for learning and engagement can guide the design of their learning experiences. In times like the past year, when a pandemic has raised concerns about students' mental health and the importance of social-emotional learning, designing for and assessing what we value and hope for our students has come to the forefront. As remote learning continues, in one form or another, teachers can continue to

consider what they value for learning and engagement and use that to guide the design of their learning experiences beyond the content knowledge and skills of their course.

Limitations

There are certain limitations to these findings. First, this research was conducted in the middle of the school year while teachers were still teaching and the AbD PGH community was still meeting. With the unpredictability of schooling, teachers may yet gain new insight into assessing maker-education. Secondly, the sample size of teachers is small and relatively homogenous. Our sample for the teachers we interviewed was purposively selected (Creswell, 2013), but all teachers within the study were already engaged in a professional learning community that focused on values-based assessment. Teachers in the community were primarily elementary school teachers, and the focal teachers who were interviewed were STEAM teachers. These focal teachers did not have specific content standards they needed to address. Additionally, because of the relationship that the researchers had with the teachers, the focal teachers were known to be actively supporting maker-based experiences remotely. Expanding to teachers of different grades and content areas might reveal interesting variations in what the teachers are assessing, how they are assessing, and how they are designing for their content-area learning goals.

Conclusion

This paper shares emerging research about assessment in remote maker-based learning and sheds light on what is happening in remote and hybrid maker-based classes. It allows us to consider potentially useful shifts in instructional practice moving forward. Through their remote instruction, the teachers in this study broadened their goals for learning, both maintaining their established vision for learning while also supporting emotional well-being and joy. In addition, teachers used the affordances of digital technologies to have students document their learning process. This not only involved students in the assessment process, but also it created chances for student expression. Together, the collection of student documentation created portfolios for students. Finally, the teachers shifted their maker activities to low-tech tools and materials to ensure accessibility for all students. In turn, this gave students opportunities to choose materials on their own and also refocused the teachers' attention on how maker activities can specifically address their learning goals.

Declarations

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Research involving human participants and/or animals Approval for this study was obtained from the Institutional Review Board of the University of Wisconsin-Madison. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Informed Consent Informed consent was obtained from all individual participants included in the study.

References

- Barton, A., Tan, E., & Greenberg, D. (2017). The makerspace movement: Sites of possibilities for equitable opportunities to engage underrepresented youth in STEM. *Teachers College Record*, 119(6), 1–44.
- Bevan, B. (2017). The promise and the promises of Making in science education. *Studies in Science Education*, 53(1), 75–103.
- Bevan, B., Ryoo, J. J., & Shea, M. (2017). What If? Building Creative Cultures for STEM Making and Learning. *Afterschool Matters*, 25, 1–8.
- Bird, C. M. (2005). How I stopped dreading and learned to love transcription. *Qualitative Inquiry*, 11(2), 226–248.
- Brahms, L., & Crowley, K. (2016). Learning to make in the museum: The role of maker educators. In K. Peppler, E. R. Halverson, & Y. B. Kafai (Eds.), *Makeology: Makerspaces as learning environments* (Vol. 1, pp. 15–29). Routledge.
- Chang, S., Penney, L., Wardrip, P., Anderson, A., Craddock, I., Martin, C., Millerjohn, R., & Stone, N. (2019). Opportunities and Vignettes for Library Makerspaces. Maker Ed and the University of Wisconsin Madison. White Paper
- Clapp, E. P., Ross, J., Ryan, J. O., & Tishman, S. (2016). *Maker-centered learning: Empowering young people to shape their worlds (First edition)*. John Wiley & Sons.
- Corbin, J., & Strauss, A. (2008). *Basics of Qualitative Research (3rd ed.): Techniques and Procedures for Developing Grounded Theory*. Thousand Oaks, CA: Sage.
- Creswell, J. W. (2013). *Qualitative Inquiry & Research Design: Choosing among five approaches* (3rd ed.). Sage.
- Cun, A., Abramovich, S., & Smith, J. M. (2019). An assessment matrix for library makerspaces. *Library & Information Science Research*, 41(1), 39–47.
- Dorph, R., & Cannady, M. (2014). *Making the future: Promising evidence of influence*. Lawrence Hall of Science & Cognizant. Retrieved from: <http://www.cognizant.com/SiteDocuments/Cognizant-making-the-future.pdf>
- Eriksson, E., Heath, C., Ljungstrand, P., & Parnes, P. (2018). Makerspace in school—Considerations from a large-scale national testbed. *International Journal of Child-Computer Interaction*, 16, 9–15.
- Gardner, H. (1989). Zero-based arts education: An introduction to ARTS PROPEL. *Studies in Art Education*, 30(2), 71–83.
- Gillies, R. M., & Boyle, M. (2011). Teachers' reflections of cooperative learning (CL): A two-year follow-up. *Teaching Education*, 22(1), 63–78.
- Gorin, J. S. (2014). Assessment as Evidential Reasoning. *Teachers College Record*, 116(11), 1–26.
- Gutwill, J. P., Hido, N., & Sindorf, L. (2015). Research to Practice: Observing Learning in Tinkering Activities. *Curator: The Museum Journal*, 58(2), 151–168.
- Hadad, R., Thomas, K., Kachovska, M., & Yin, Y. (2020). Practicing Formative Assessment for Computational Thinking in Making Environments. *Journal of Science Education and Technology*, 29(1), 162–173.
- Hsu, Y.-C., Baldwin, S., & Ching, Y.-H. (2017). Learning through Making and Maker Education. *TechTrends*, 61(6), 589–594.
- Hughes, J., & Morrison, L. (2018). The Use of E-Textiles in Ontario Education. *Canadian Journal of Education*, 41, 356–384.
- Jones, S., Bailey, R., Brush, K., & Kahn, J. (2018). *Preparing for effective SEL implementation*. Boston, MA: Harvard Graduate School of Education. Retrieved from <https://www.wallacefoundation.org/knowledge-center/Documents/Preparing-for-Effective-SEL-Implementation.pdf>
- Keune, A., Thompson, N. A., Peppler, K. A., & Chang, S. (2017). “My portfolio helps my making”: Motivations and mechanisms for documenting creative projects in out-of-school makerspaces. In L. Mikos & I. Eleá (Eds.), *Young and creative: Digital technologies empowering children in everyday life* (pp. 145–158). Gothenburg, Sweden: Nordicom.
- Kim, Y., Eduard, K., Alderfer, K., & Smith, B. (2018). *Making culture: A national study of educational makerspaces*. Philadelphia, PA: Drexel ExCITE Center.
- Kumar, V., Millerjohn, R., & Wardrip, P. (2019). Designing Tools for Observation and Assessment in Makerspaces. *Proceedings of FabLearn 2019 on - FL2019*, 197–200.
- Lin, Q., Yin, Y., Tang, X., Hadad, R., & Zhai, X. (2020). Assessing learning in technology-rich maker activities: A systematic review of empirical research. *Computers & Education*, 157, 103944.
- Lincoln, Y. S. (1995). Emerging criteria for quality in qualitative and interpretive research. *Qualitative Inquiry*, 1(3), 275–289.
- Lincoln, Y. S. & Guba, E. G. (1985). *Naturalistic inquiry*. Thousand Oaks, CA, Sage.
- Maltese, A. V., Simpson, A., & Anderson, A. (2018). Failing to learn: The impact of failures during making activities. *Thinking Skills and Creativity*, 30, 116–124.
- Martin, C. K., Reyes, E., Ramirez, E., Brahms, L., & Wardrip, P. (2020). *Supporting Educator Reflection and Agency Through the Co-Design of Observation Tools and Practices for Informal Learning Environment* (J. H. Kalir & D. Filipiak, Eds.; Vol. 1). Pittsburgh, PA: ETC Press.
- Maxwell, J. A. (2013). *Qualitative research design: An interactive approach* (3rd ed.). Sage.
- McTighe, J. (2018). Three key questions on measuring learning. *Educational Leadership*, 75(5), 14–20.
- Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass.
- Mersand, S. (2020). The State of Makerspace Research: A Review of the Literature. *TechTrends*, 65(2), 174–186.
- Mislevy, R. J., Almond, R. G., & Lukas, J. F. (2003). A Brief Introduction to Evidence-Centered Design. (Research Report RR-03-16). Educational Testing Service. Retrieved from: <https://www.ets.org/Media/Research/pdf/RR-03-16.pdf>
- Morse, J. M., Barrett, M., Mayan, M., Olson, K., & Spiers, J. (2002). Verification Strategies for Establishing Reliability and Validity in

- Qualitative Research. *International Journal of Qualitative Methods*, 1(2), 13–22.
- Murai, Y., Kim, Y. J., Chang, S., & Reich, J. (2020). *Principles of Embedded Assessment in School-Based Making*. Retrieved from: <https://edarxiv.org/amvs2>
- Pellegrino, J., DiBello, L., & Goldman, S. (2016). A framework for conceptualizing and evaluating the validity of instructionally relevant assessments. *Educational Psychologist*, 51(1), 59–81.
- Peppler, K., & Keune, A. (2019). “It helps create and enhance a community”: Youth motivations for making portfolios. *Mind, Culture, and Activity*, 26(3), 234–248.
- Rayna, T., & Striukova, L. (2020). Fostering skills for the 21st century: The role of Fab labs and makerspaces. *Technological Forecasting and Social Change*, 120391.
- Saldaña, J. (2015). *The coding manual for qualitative researchers* (3rd ed.). SAGE
- Sanders, R. K., Kopcha, T. J., Neumann, K. L., Brynteson, K., & Bishop, C. (2019). Maker’s Workshop: A Framework to Support Learning through Making. *TechTrends*, 63(4), 386–396.
- Shepard, L. A. (2000). The role of assessment in a learning culture. *Educational Researcher*, 29(7), 4–14.
- Stiggins, R., & Chappuis, J. (2005). Using student-involved classroom assessment to close achievement gaps. *Theory into Practice*, 44(1), 11–18.
- Vossoughi, S., Hooper, P., & Escudé, M. (2016). Making Through the Lens of Culture and Power: Toward Transformative Visions for Educational Equity. *Harvard Educational Review*, 86, 206–232.
- Vuorikari, R., Ferrari, A., & Punie, Y. (2019). *Makerspaces for Education and Training: Exploring future implications for Europe* (No. JRC117481). Joint Research Centre (Seville site).
- Wardrip, P. S., & Brahms, L. (2020). Supporting learning in museum makerspaces: A National Framework. *Journal of Museum Education*, 45(4), 476–483.
- Wardrip, P., Evancho, J., & McNamara, A. (2018). Identifying what matters. *Phi Delta Kappan*, 99(6), 60–63.
- Wardrip, P. S., & Brahms, L. (2015). Learning practices of making: developing a framework for design. In *Proceedings of the 14th international conference on interaction design and children* (pp. 375–378).
- Wardrip, P. S., & Brahms, L. (2016). Taking making to school. In K. Peppler, E. Halverson & Y.B. Kafai (Eds.), *Makeology: Maker-spaces as learning environments* (Vol. 1, pp. 97–106). Routledge.
- Wardrip, P., & Ryoo, J. (2020). The Role of Educational Technology in Informal Learning Environments: Making and Tinkering. In *Handbook of Research in Educational Communications and Technology* (pp. 505–518). Springer, Cham.
- White House. (2014). *President Obama to host first-ever White House Maker Faire* [Press release]. FACT SHEET: President Obama to Host First-Ever White House Maker Faire. Retrieved from: <https://obamawhitehouse.archives.gov/the-press-office/2014/06/18/fact-sheet-president-obama-host-first-ever-white-house-Maker-faire>
- Wiggins, G. (1998). *Educative Assessment*. Jossey-Bass.
- Xi, Q., Wu, W., & Zhang, Y. (2017). Makerspace activities in China. *Science & Technology Libraries*, 36(4), 425–433.

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