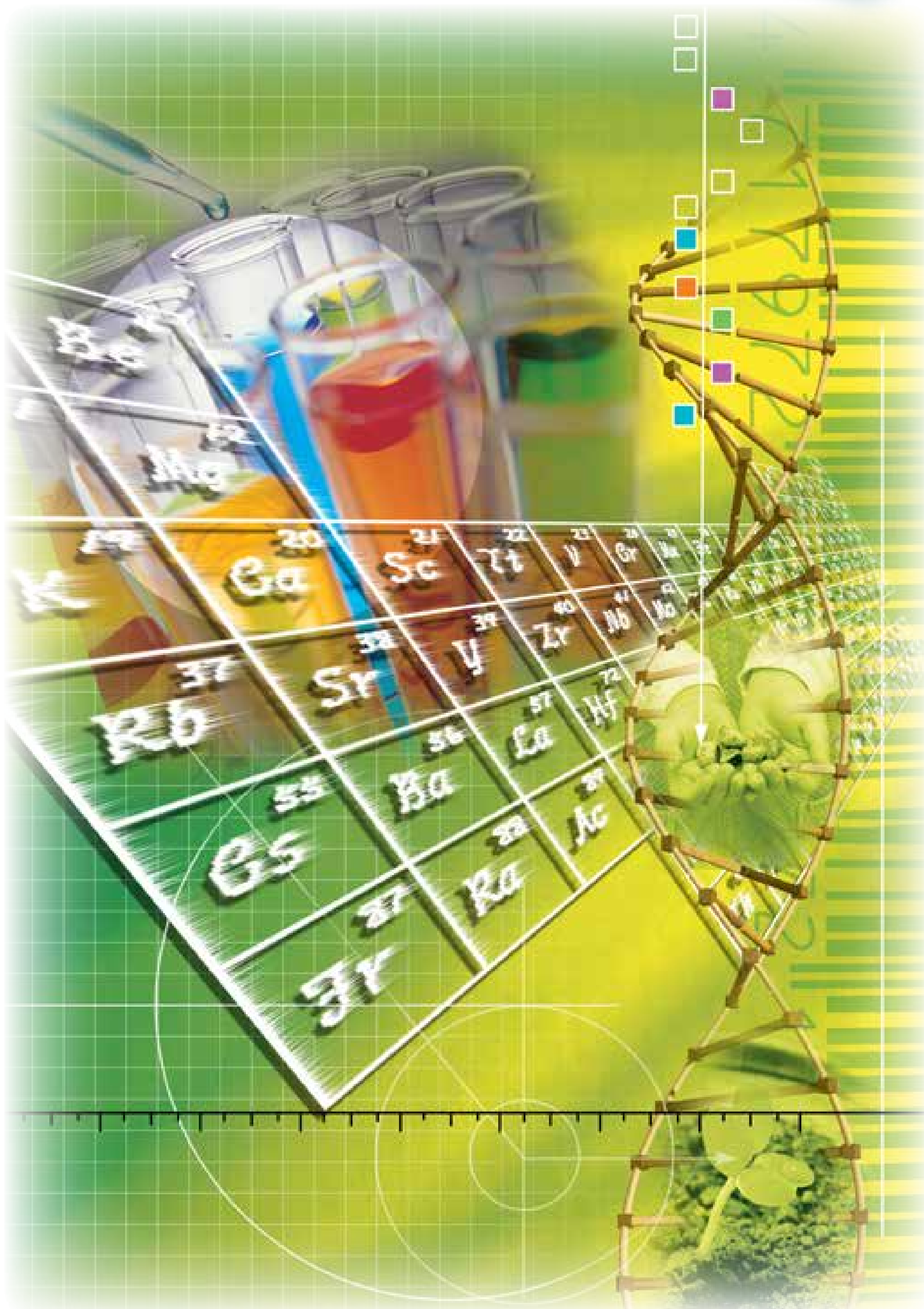
Alberta Science Education Journal

Vol 45, No 2
April 2018



a publication
of the
Science Council
of the
Alberta Teachers'
Association

It's More Than Just Making: Insights into Facilitating Learning Through Making

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Abstract

Makerspaces are a rapidly growing trend in education. Schools are incorporating makerspaces to provide students with experiential learning opportunities to be designers, innovators and makers. Attention must be given not only to the creation of such spaces but also, and more important, how to incorporate such activities in an environment that fosters deep learning. In this article, a team of researchers share their lived experience of implementing makerspace activities with students in a school of education. From reflecting on our experience designing and facilitating learning through making, we have identified three lessons learned: designing challenging learning tasks is not easy; facilitating learning through making is a delicate dance; and changing our dispositions through making changes our practice. Learning in makerspace environments is as challenging for teachers as it is for their students because it connects the development of iterative design provocations and a mindset that embraces failure.

Introduction

Making and the makerspace movement is a fast-growing trend embraced by learning commons (Klipper 2014) and emerging in K–12 schools (Johnson et al 2014, 2015). A makerspace is a gathering space for inventors and innovative thinkers to access tools and technology to design, plan and produce solutions to problems (Bevan, Petrich and Wilkinson 2015). Students in makerspaces are able to design and build prototypes and create machines, games and/or solutions using a range of materials from low tech (eg, paper) all the way up to high tech (eg, 3-D printers). The addition of an array of digital technologies adds to the boundless potential for rapid prototyping. A makerspace in the K–12 setting is more than a resourced space where students can play with materials. Rather, it is a learning environment in which students are designers, innovators and makers.

The purpose of this article is to share reflections of our lived experience of designing and facilitating learning through making in an informal learning commons context. We begin by providing an overview of *making*, *maker* and *makerspace*, why they are emerging in school and the possible shift developing in education as a result of the maker movement. Next, we examine insights from a collaborative partnership with a library's technology instructor who is leading the maker movement in our higher education library and a team of researchers from a school of education, focused on learning through making. Finally, we share three lessons learned from our practice in designing and implementing a series of maker events. With each iteration of our work as facilitators and researchers, we are learning more about nurturing a maker mindset that needs to be grounded in curricular and pedagogical practice.

Maker, Making and Makerspaces

The terms *maker*, *making* and *makerspace* are often used without giving careful consideration to how they are defined. There is no agreed-upon definition for these terms (Martin 2015; Vossoughi and Bevan 2014). *Making* is considered a creative process (Willett 2016) and is sometimes associated with such terms as *tinkering*, *hacking* and *fabrication*, whereas makers design and build objects using physical and digital tools (Bevan et al 2015; Ryan et al 2016). While making involves creating and prototyping, a *maker* is an individual who engages in making in a highly personal way. A maker is "good at improvising: they are able to do things that have no instructions" (Dougherty and Conrad 2016, 144). Students in a maker environment participate in making by ideating and solving problems of interest to them; "[t]he process of realizing an idea and making it tangible is what defines a maker" (Dougherty and Conrad 2016, 144).

This work of making takes place in a *makerspace*, a participatory social environment in which people of different levels of skill and expertise work alongside each other to create and invent. Makerspaces are "constructivist spaces" (Fourie and Meyer 2015, 521)—flexible, community spaces, particularly well suited to libraries or learning commons, where groups and individuals can come together to hypothesize, explore and experiment as a means to deepen their own learning. As noted by Horvath and Cameron (2015), "making things allows students to try something, see what works, fix problems, and carry on" (p 60). In this physical space, there are tools and materials available for constructing, fabricating and testing. In an educational makerspace context that would be found in a school's learning commons, one would find boxes, buckets and baskets housing a variety of materials ranging from low technology (eg, wood blocks, Lego, paper, fabric, duct tape, and sets of scissors, pliers and screwdrivers) up to high-technology items such as digital kits, 3-D printers, and various digital devices (eg, Arduino, Makey Makey, Raspberry Pi). In their essence, makerspaces are places where tools are accessible for students to construct or deconstruct objects and projects, "embracing tinkering, or playing, in various forms of exploration, experimentation and engagement, and fostering peer interactions as well as the interests of a collective team" (Wong 2013, 35).

With the ongoing growth of the maker movement, terms such as *innovation lab*, *design lab*, *hackerspace*, *fab lab* and *science lab* (Peppler et al 2015) have been used to describe such spaces. Regardless of the specific term used, makerspaces tend to allow users to select their own activities in an environment that is supportive, playful and collaborative, and where trial and error is encouraged (Oliver 2016a).

A review of the literature indicates a prevalent focus on *what* makerspaces are and *how* such spaces are created (Good 2013; Haug 2014). In addition to that, we need to also uncover the educational benefits that may arise from makerspaces. The National Science Foundation, for instance, is funding research (Learning in the Making) to examine the educational benefits of makerspaces and the transference of this learning to improving skills in math and science (Johnson et al 2014). For example, Vanderbilt University and the University of Michigan's Center for Entrepreneurship are involved in work with makerspaces focused to foster experiential learning and student leadership (Johnson et al 2014). Over 50 per cent of those surveyed through Georgia Tech noted that their GPAs were positively affected by time spent at their makerspace innovation studio (Forest et al 2014, 21).

Traditional approaches to learning are "typically structured such that any failure would get a bad grade. Learning by making allows for experimentation in ways that are difficult to teach through books, lectures, papers and quizzes" (Horvath and Cameron 2015, 60). By allowing students a space to experiment with solutions—failing sometimes, succeeding at others—in order to construct their own knowledge about the situation, makerspaces may be one of the innovations that Papert (1991) envisioned that would "produce radical change in how children learn" (para 18). Within this shift from traditional learning to learning through making, "students can learn and create together, integrating content- and product-centered activities as part of their instruction" (Johnson et al 2014, 14). As such, educational makerspaces are prime opportunities to incorporate Papert's notion of constructionism (Kurti, Kurti and Fleming 2014a), where one could combine digital and physical artifacts or "objects to think with" (Papert 1980, 23) to elaborate new solutions to a given problem. However, for such benefits to be obtained, educational makerspaces need to be more than a resourced space that comes with the perspective of "have at it."

As more K–12 schools, along with their learning commons, are establishing physical spaces with tools and materials (eg, 3-D printers, digital kits), we also see a greater need for librarians and teachers to be able to scaffold and facilitate learning opportunities that foster creativity, where the students are encouraged to be innovators or makers. The complexity of this shift requires teachers and librarians to create maker tasks or offer opportunities for problems to be identified and/or solved through purposeful design, collaboration and risk taking that may include rapid prototyping. It is in these learning environments that we need to foster collaboration, creativity and iterative, creative solutions so that students can develop a maker mindset (Dougherty 2013; Paganelli et al 2017). A key challenge with makerspaces, according to Horvath and Cameron (2015), is the range of skills required by the teachers and/or librarian. No one person has the needed knowledge or skills to facilitate such learning. As Horvath and Cameron argued, "a combination of comfort with traditional shop class methods plus electronics plus competence in computer programming" (p 5) is what teachers need to facilitate learning through making. As such, within schools, it may require developing specifics skills but also working with others to support making. One approach to developing such skills, as noted by Horvath and Cameron, is to "gather a diverse group of colleagues to try out some joint interdisciplinary projects" (p 207). Experience and competence of a diverse group will help support the learning.

Fostering a Maker Mindset

The concept of a maker mindset originated from Dweck's (2006) work on growth mindsets, in which the iteration of ideas and embracing of failure is seen as an opportunity to learn. Scholars suggest that the maker mindset empowers students because it provides opportunities to develop perseverance, problem solving and thinking abilities (Cermak-Sassenrath and Møllenbach 2014; Oxman Ryan et al 2016). Some see the development of the maker identity or mindset being as important as the skills and knowledge (Chu et al 2015) acquired through making.

The development of the maker mindset is as critical for teachers as it is for students. Litts (2015) observed that "facilitators' ability to support making activities was severely limited by their own maker identity" (p 349). To gain the effects of makerspaces, teachers must take on the characteristics of the maker mindset, including persevering, problem solving and embracing failure as a part of learning. Whether for teachers or students, a "maker mindset is an expression of the growth mindset that is evident in a maker's willingness to learn new tools and methods as well as experiment without certainty of success" (Dougherty and Conrad 2016, 145).

One way in which the maker mindset is enacted during a pedagogical transaction is through a dynamic relationship in terms of the role of student and teacher. Maker education, whether in informal or formal environments, gives ownership of learning to students, but in a self-directed and participatory manner (Fleming 2015). During maker projects, learners follow their interests (Oliver 2016b), and different arrangements are constantly made between students, peers and instructors. As noted by Fleming (2015), at times students may be learning with and from colleagues and the instructor, yet at other times they may be in a teaching role with peers and with the instructor. Layering into this complexity is the changing role of the teacher. Working more in a fluid role as a facilitator in these maker environments requires teachers to be both risk-takers and learners. Further, Fleming (2015) found that, at times, the teacher's role may also be that of "an observer, intervening only when further rigor or the need to pass on a gem of wisdom from experience becomes necessary" (p 47). At the same time in this dynamic role, teachers and librarians are learning to navigate making in order to support deep learning. They become "spacemakers" (Kurti, Kurti and Fleming 2014b, 11), responsible for establishing the environment of discovery that is inherent to makerspaces.

Research Design

A design-based research (DBR) methodology is "a series of approaches, with the intent of producing new theories, artifacts, and practices that account for and potentially impact learning and teaching in naturalistic settings" (Barab and Squire 2004, 2). This flexible methodology is designed to "improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories" (Wang and Hannafin 2005, 6–7). This design allows for the implementation of the innovation (makerspace) and the study of the iterations of the use of the makerspace over time. Through DBR, a collaborative approach has been used to study the design, implementation and facilitation processes for the creation of a series of makerspace initiatives. Two questions guided our DBR inquiry: (1) What are the essential conditions needed to build capacity of instructors who facilitate learning in makerspace environments? and (2) How does the design of a makerspace learning task influence teaching and learning practices?

Through the iterative process and the ongoing discussion of our research team in response to the various planned initiatives and data collected, we continue to learn of conditions and factors that influence the facilitation of learning using a maker approach. This article outlines reflections and insights from our lived experience with the initial year's collaborative work in terms of design, implementation and facilitation in support of learning through making.

Our Maker Team's Context

In 2015, the Education branch library at our university began to develop a makerspace environment. The library's technology instructor investigated the maker movement and engaged in various learning opportunities regarding makerspaces. Soon after, resources and materials were purchased. In order to prototype making for learning in a cost-effective and less obtrusive manner, the decision was made to house the resources and materials in a mobile makerspace, a large rolling tool chest purchased at a hardware store that could be moved to different locations as needed and tucked away when not in use.

We were curious about a variety of aspects such as task design, development of 21st-century skills through making, and the assessment of learning in this process. Through mutual interest in makerspaces, we formed our design-based research team: a librarian (specifically, the library's technology instructor), responsible for leading the making initiative; two doctoral students who actively engaged in supporting not only selected maker activities but also learning the research; and an academic charged with leading the study.

Over 12 months, we offered various maker activities to undergraduate and graduate students and faculty. This article highlights four of these initiatives, showcasing the range of work that occurred.

1. An event entitled Evil Genius was a three-part research series in which undergraduate students were involved in prototyping and testing with high- and low-tech tools. Each session of this series lasted 1.5 hours and was organized around challenges that needed to be solved in groups within the allotted time frame.
2. A series of half-hour workshops, entitled Black Chair Sessions, designed to be hands-on workshops focused on introducing undergraduate education students to makerspace tools and kits (eg, littleBits, Makey Makey).
3. Think. Design. Make was a three-part summer series providing participants with the experience of working through the design-thinking process, from identifying a problem all the way to prototyping a design.
4. A Spotlight area was established in the library that provided the testing of open-ended making opportunities (eg, knitting, marble runs, paper airplanes, paper design, bridge building, deconstruction).

The various offerings of maker activities have given the team an opportunity to reflect on our own learning and to use that to inform next steps. In particular, after maker events, the team met to debrief, reflect and develop a plan of action leading to the next iteration.

Lessons Learned

Through our ongoing team meetings and reflective process, three preliminary findings emerged from our work in terms of designing, implementing and facilitating learning through makerspaces:

- Designing challenging learning tasks is not as easy as one would expect.
- Facilitating learning through making is a delicate dance.
- Changing our dispositions through making changes our practice.

Designing Challenging Learning Tasks

In our first maker series, Evil Genius, we came to see that designing rich, relevant learning tasks is easier said than done. Part of the process was about giving ourselves permission to view each session as our own learning opportunity in terms of what and how we supported learning through the maker activity. We debriefed after each event and discussed what worked and what could be improved. With the Evil Genius series, we designed each task to be progressively more complex, moving from low-tech (eg, create a game using cards, dice and blocks) to a mix of low- and high-tech solutions (eg, littleBits and Makey Makey). We observed that the constraints built into the task design that fostered greater complexity in the work resulted in a less successful learning experience for some of the students. For example, one task involved the use of Makey Makey, an invention kit that allows students to use ordinary materials to create switches or controllers. In this task, groups were charged with using Makey

Makey to design a switch to time a toy car's speed. Students used the Scratch game on the Makey Makey site to guide the data collection without having to do the programming. As we observed two groups, we found it interesting to see how one group, when encountering difficulty, shut down, whereas the other group built on each other's ideas and appeared delighted when they accomplished the task. Observing how each group approached the task differently, we asked questions such as these:

- Why did one group give up?
- With the advancement of the complexity of tasks, was greater scaffolding required to support *how* and *why* to use the various tech-solutions?
- Was more time needed to lead into each making task?
- Were the students uncomfortable with being in this place of unknowing? and
- What did we need to explore in the task design that would make the work more fulfilling for *all* participants?

We grappled with these questions as a result of the experience. These questions helped us to rethink the design, and also the nature of our facilitation.

The library's technology instructor, who participated in all makerspace activities, felt that the less structured design of the Black Chair sessions, as compared to Evil Genius, was more successful for the students. For example, during a littleBits half-hour hands-on learning session, the first part of the session was dedicated to discovery, with the second part connecting the use of the kit with curriculum outcomes. A possible explanation for the greater sense of success could be that the focus was on one technology, prompting participants to engage in rich discussions about the use of the particular tool in interdisciplinary curriculum settings. As a team, we did come to see that for student engagement, tasks needed to be authentic and student driven, and that documenting the process could serve as a reflection tool for prototyping enhanced session design solutions.

Facilitating Learning Through Making

Makerspace learning is messy but engaging. It is learner centred, inquiry based, interdisciplinary and technology enhanced for both students and instructors. It is implicitly creative, imaginative and process driven, allowing for differentiated problem solving that leads to more questions and deeper learning. It is in this space that the teacher plays a key role in helping students to make the curricular connections, to challenge their thinking and to guide the development of critical professional or 21st-century skills.

It is a delicate balance of knowing when to step in and when to step out, and of leading the learning. When will a demonstration or giving of guidance be helpful, in contrast to giving students more time to grapple with the learning? Along with the timing, we also found the need to be skilful in asking probing and/or linking questions to better scaffold the learning. The ability to observe and listen to the conversations occurring during the making and then to provide the necessary guidance and support by the instructor to foster the learning is a skilful art that needs to be developed in those who facilitate learning in makerspaces. For instance, in the first Evil Genius event, as facilitators we tended to stand back and let participants explore and engage in the task. Upon reflection, we felt that this particular group could have benefited from greater guidance. This made us realize that facilitating learning through making depends on our responsiveness in relation to learners and the learning task.

With makerspace learning, teachers must allow substantial time not only for their students but also, and just as importantly, for themselves to think, design, prototype, test and retest as part of the maker learning experience. Time provides opportunities for the exchange of collaborative peer feedback through multiple iterations, while embracing failure as fortuitous for rich learning, which turns the focus to process rather than a hurried, final solution. This means being aware of the fluidity of knowing and not knowing, of developing insights over time and iterations, and of learning not in scheduled time blocks but through ongoing experiences.

Changing Our Dispositions Through Making

The collaborative nature of making challenges teachers to let go of control and look beyond themselves for expertise. This can be done by encouraging all members of the immediate maker community to provide input and lead aspects of the design process, depending on their strengths and background knowledge. It allows teachers to see the possibilities for interdisciplinary connections across curricular areas and validates the complexity and "messiness" of rich teaching and learning, taking their own learning beyond the conventional notion of what it means to be literate. For example, Black Chair sessions allowed teachers to see the creative ways that participants used a photography app to capture artifacts while documenting the process with written comments. In a way, teachers need to embrace the spirit of making in their own preparation—tinkering, experimenting and designing solutions to the situations that arise.

Teachers who facilitate learning through making need to be confident and willing to ask for outside expertise when needed, and to create conditions so that students draw on the expertise within their own group. For example, in planning the Think. Design. Make session, the library's technology instructor called on 3-D printing experts to assist. Students in the Evil Genius session using Makey Makey declined the offer of a short video explaining the technology they were to use. Rather, they wanted time to mess around with the kit; they demonstrated a sense of pride and accomplishment when they were able to prototype a solution themselves. Teachers need to have the confidence to assess the situation and determine where and how expertise can be brought into the learning in a timely and appropriate manner.

Conclusion

As teachers embrace learning through making in the K–12 and postsecondary contexts, care needs to be taken that making is more than creating a space and resourcing it with various materials (eg, kits, computers). A critical factor for implementation is the willingness of teachers to take risks, accept failure, embrace the unknown and rely on the collaborative knowledge and expertise of all, while providing time for students and themselves to iterate solutions when designing and facilitating within a makerspace learning environment.

Taking time to reflect on our lived experience has helped us learn how to better facilitate learning through making. With the expansion of the maker movement, teachers need to become aware of and develop an appreciation for the intricacies of designing and facilitating learning through making. Through our own learning with designing and facilitating maker activities, we, too, are living the maker and making experience. After all, it is more than just making.

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