MakerMinds: An Exploratory Study of Making and Mindfulness Pedagogies

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Abstract

The purpose of this ethnographically informed research study was to explore the integration of making and mindfulness pedagogies in a single curricular intervention ("MakerMinds") and, in particular, how making engages students in mindfulness content and encourages their independent use of mindfulness tools. Mindfulness programs have long been used to promote mental health in clinical and non-clinical settings. Related research with school-aged children is limited, however, and the problem of how to fully engage them in mindfulness programming remains unsolved. Here, we report on the experiences of 24 Grade 4 students in MakerMinds over an eight-week period. Qualitative data from multiple sources revealed a program successful in engaging students and encouraging their application of mindfulness tools as needed in their daily lives. It also positively impacted conceptual and experiential knowledge of mindfulness and developed students' agentic awareness of themselves as problem-solving makers and nascent mindfulness practitioners.

Keywords: constructionism, making, makerspace, meditation, mental wellness, mindful learning, mindfulness, student wellness

Résumé

Le but de cette recherche ethnographique était d'explorer l'intégration des pédagogies de la fabrication et de la pleine conscience dans une intervention curriculaire unique (« *MakerMinds* »). Plus particulièrement, de découvrir comment la fabrication engage les élèves dans le contenu de la pleine conscience et encourage leur utilisation indépendante des outils de pleine conscience. Les programmes de pleine conscience sont utilisés depuis longtemps pour promouvoir la santé mentale dans des milieux cliniques et non cliniques. Cependant, les recherches connexes auprès d'enfants d'âge scolaire sont limitées et la question sur la façon de les impliquer pleinement dans les programmes de pleine conscience demeure ouverte. Nous rapportons ici les expériences de 24 élèves de 4e année qui ont suivi l'intervention curriculaire *MakerMinds* sur une période de 8 semaines. Des données qualitatives provenant de plusieurs sources ont révélé un programme parvenant à impliquer les étudiants et à les encourager à utiliser les outils de pleine conscience dans leur vie quotidienne. Cela a également eu un impact positif sur les connaissances conceptuelles et expérientielles de la pleine conscience et contribué à développer l'agentivité des élèves en tant que concepteurs de solutions et praticiens émergents de la pleine conscience.

Introduction

Mindfulness programs have become an increasingly popular method of supporting mental wellness in Western secular settings, including schools. Training in mindfulness has proven effective for promoting mental well-being amongst adults and, though the studies are limited, amongst children and youth as well (Beauchemin et al., 2008; Flook et al., 2010; Gouda et al., 2016; Kabat-Zinn, 2013; Meiklejohn et al., 2012). However, these programs often struggle to fully engage the interests or attention of many young people (Britton et al., 2014; Maloney et al., 2016; Milligan et al., 2013). Given the abstract, intangible nature of the core content of any mindfulness program, in addition to the necessary elements of silence and stillness that might be challenging for some children to embrace, this struggle with engagement is perhaps not surprising.

To address this issue, we adapted the pedagogical approach commonly used in mindfulness programs to better meet the particular educational needs and interests of children. To date, there are no programs in the literature that approach the core content of mindfulness training using student-led, project-based, and hands-on approaches to learning like those found in makerspaces (Blikstein, 2013; Halverson & Sheridan, 2014; Sheridan et al., 2014). In an attempt to create and implement an engaging mindfulness program for young students, the pedagogies of mindfulness and making were carefully and deliberately interwoven. In this article, we report on the initial exploratory study of this unique curricular intervention and, in particular, on how the two pedagogies interacted when carried out together.

Background

Mental Wellness in Children and Youth

This study took place in Ontario, Canada, where the number of children and youth diagnosed with a mental health disorder affects about one in five children (Ontario Ministry of Education, 2013b). South of the border, the situation appears to be similar: A 2010 study out of the University of Michigan confirms that approximately one in every four to five youth in the United States meets criteria for a mental disorder (Merikangas et al.,

2011). In addition, adolescence is known to be the most common period for the onset of these disorders (Gouda et al., 2016; Kessler et al., 2005; Paus et al., 2008) with the World Health Organization (2018) stating that, globally, half of all mental health conditions begin before the age of 14.

Unfortunately, excessive wait times and prohibitive costs make access to treatment problematic (Centre for Addiction and Mental Health [CAMH], 2018). In Ontario, for example, the current wait times for psychological support through public services can be up to one year, and the cost for private therapy can be prohibitive (CAMH, 2018). To make matters more challenging, the schools where young people spend most of their time can be a main source of stress in students' lives, rather than a source of mental health support (Broderick & Metz, 2009; Cohen, 2006; Gouda et al., 2016; Ontario Ministry of Education, 2013a). It is perhaps for all of these reasons that there is evidence of growing interest among educators in providing mental health programming (Ontario Ministry of Education, 2013b; Whitley et al., 2013). In the next section, we overview the literature related to mindfulness, connecting it where possible to school-based settings. We then review the existing literature on makerspaces and their use in schools. To our knowledge, there have been no studies to date that integrate mindfulness and makerspace pedagogies.

Related Literature: Mindfulness and Making

Why Mindfulness?

Mindfulness has its roots in centuries-old Theravada Buddhism (Hahn, 1976). Though the exact, nuanced nature of mindfulness is the subject of ongoing debate (Grossman, 2008), there is a general consensus to be found amongst scholars that mindfulness is an awareness that emerges from bringing non-judgemental and focused attention to each moment of one's experience (Bishop et al., 2004; Broderick & Metz, 2009; Gouda et al., 2016; Kabat-Zinn, 2013; Lutz et al., 2008; Meiklejohn et al., 2012; Paneduro, 2016; Poulin, 2009; Shapiro et al., 2006). It is an "*awareness that arises by paying attention on purpose*" that is distinct from the act of thinking, instead being a powerful and "complementary form of intelligence" (Kabat-Zinn, 2013, p. xxxv, emphasis in original). This awareness provides an interlude, a pause, in which a mindfulness practitioner might craft and carry out responses to events—including thoughts and emotions—rather than simply reacting to them.

Inherent in a state of mindfulness is a specific mode of attention known as metacognition (Flavell, 1979). Bishop et al. (2004) contend that mindfulness is a metacognitive process "since its evocation would require both control of cognitive processes (i.e., attention self-regulation) and monitoring the stream of consciousness" (p. 11). To think about one's own thinking, to experience thoughts as merely thoughts and not necessarily as reflections of reality, to choose whether or not to engage with each thought, and to be able to disengage from harmful thoughts—these are skills produced by the metacognitive aspect of mindfulness. These skills have powerful implications for emotion regulation and therefore for mental health.

To better understand the current popularity of mindfulness programs to promote mental health, a quick overview of the work of Jon Kabat-Zinn, who founded the Mindfulness-Based Stress Reduction (MBSR) program at the University of Massachusetts Medical Center in 1979, is necessary. For almost 40 years, the MBSR program has trained practitioners to develop their capacity for mindfulness through an eight-week-long course involving intensive use of various meditation techniques. This program has been highly influential in a growing body of scientific research on the subject of mindfulness within medicine, as well as a large number of other disciplines, including the field of education (Kabat-Zinn, 2013).

An overwhelming proportion of this research aims to measure the impact of mindfulness on a broad array of outcomes related to mental health and well-being. For example, studies have linked mindfulness training to significant increases in self-acceptance (Broderick & Metz, 2009), self-perception of physical health (Poulin, 2009), as well as empathy and compassion (Davidson et al., 2003; Shapiro et al., 1998, 2007). Mindfulness training is also associated with reduction of negative affect (Broderick & Metz, 2009), increases in positive affect (Davidson et al., 2003; Shapiro et al., 2007), significant reductions in stress (Bruce et al., 2002; Gouda et al., 2016; Paneduro, 2016; Shapiro et al., 1998; Williams et al., 2001), improvements in interpersonal problems (Biegel et al., 2009; Gouda et al., 2016), enhanced coping skills (Garland et al., 2011; Garmon et al., 2014; Poulin, 2009), and overall improvements in well-being (Shapiro et al., 1998).

There are growing efforts to introduce mindfulness-based programs into schools, yet there is a paucity of research related to mindfulness training with children and youth due to a number of constraints, including important ethical considerations involved in working with young people, in obtaining accurate measurements and control data, and

in the sheer variety evident in the programs studied (Burke, 2009; Carsley et al., 2018; Greenberg & Harris, 2012; Semple & Burke, 2019; Zenner et al., 2014). Of the studies that have been carried out, overall findings are promising (Burke, 2009; Gouda et al., 2016; Semple & Burke, 2019), connecting mindfulness training programs for children and adolescents to improvements in anxiety and stress, in mood and overall well-being, in social skills, in attentional and executive functioning skills, and in emotional regulation (Beauchemin et al., 2008; Black et al., 2009; Broderick & Metz, 2009; Flook et al., 2010; Gouda et al., 2016; Napoli et al., 2005; Semple et al., 2005, 2010; Schonert-Reichl & Lawlor, 2010; Zylowska et al., 2008). Broderick and Metz (2009) caution, however, that "the work of bringing mindfulness to children and adolescents in schools is just beginning" (p. 43) and that there are still complex questions to be considered about how best to translate mindfulness content and activities for use with children (Jennings et al., 2012).

Why Making?

So many scholars trace current conceptions of the *makerspace* back to Piaget's constructivism and Papert's constructionism that these seem like appropriate places to begin any discussion of *making* (Blikstein, 2013; Halverson & Sheridan, 2014; Litts, 2015; Martinez & Stager, 2013; Sheridan et al., 2014). Piaget contends that learners constantly construct and reconstruct their own knowledge through personally meaningful experiences with the world. It therefore cannot be transmitted directly from one person to another. Individuals understand the world through invention (Piaget, 1973).

Papert's constructionism expands upon Piaget's view of knowledge-building by explicitly focusing on the value of working with external representations of learning. For Papert, building one's own knowledge "happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand-castle on the beach or a theory of the universe" (Papert & Harel, 1991, n.p.) An artefact "can be shown, discussed, probed, and admired" (Papert, 1993, p. 142) and it is this through which its creator represents, understands, and develops his or her own learning (Sheridan et al., 2014).

In recent years, there has been a proliferation of school and community-based makerspaces that engender student-centred, project-based, and hands-on constructionist approaches to learning. To teach through making—whether in a designated makerspace

or in a classroom—means to immerse students in an authentic, deep learning task usually toward the production of a shareable artefact. It is to provide the materials, the tools, the space, and the time for students to engage in an active and exploratory process of designing and building that is often described as "tinkering" (Resnick & Rosenbaum, 2013).

Tinkering involves students in a dialogue with whatever materials they are working with. It is an iterative approach to learning that "affords a deep conversation with the material" at hand (Peppler et al., 2016, p. 5). It opens up the possibility of students building knowledge beyond their teacher's anticipated outcomes (Thumlert et al., 2018), so unlike traditional schooling in which "learners are rushed ahead to find a solution to a predefined problem" (Sheridan & Konopasky, 2016, n.p.). Instead, a maker must overcome any number of unforeseen obstacles along the journey to a final product.

Mistakes are not only expected, they are viewed as productive "learning opportunities" (Kafai & Fields, 2018, p. 5) that require the maker to reflect, redesign, and try again. This process teaches problem-solving skills and persistence and makes the student's learning transparent. In working with e-textiles, for example, Kafai et al. (2012) claim that students were able to identify and fix mistakes throughout a "recursive" construction process (p. 190). Any gaps in a student's understanding were made conspicuous through non-working parts of an artefact as it was constructed. In another e-textiles study, Kafai and Peppler (2014) argue that making renders "simple misconceptions… apparent" (pp. 181–185). This transparency is a fundamental part of why constructionism incorporates external representations of thinking.

In addition to the iterative nature of making, learning in makerspaces is fundamentally social. This is where do-it-yourselfers eschew isolation to enjoy the social benefits and leverage the knowledge and skills of doing-it-together. After all, human learning "presupposes a specific social nature" (Vygotsky, 1978, p. 88) and individuals make sense of the world around them through social interaction, especially through language (Ackerman, 2001; Litts, 2015). The compulsion to share knowledge is therefore "a central design feature" of makerspaces, based on the understanding that "skills, knowledge, and ideas build up more quickly when everyone contributes" (Sheridan & Konopasky, 2016, p. 31). Some of this knowledge is shared via solicited and unsolicited feedback (Sheridan et al., 2014) that allows participants to learn from the mistakes and successes of others. And it is distributed as people, texts, tools, and technologies—those cultural devices central to Vygotsky's thinking—are all leveraged as sources of stored knowledge.

The community aspect of a makerspace also helps to create an encouraging atmosphere in which individual voices are heard and valued (Taylor et al., 2016). In their work with students developing anti-bullying artefacts, Hughes et al. (2016) chose the makerspace specifically for its ability to encourage the expression of voices. Maker education gives "voice to children and learners" and teaches them to "participate in acts of self-determination and…various forms of production" (Bal et al., 2014, p. 162). Understanding oneself as a producer—of both knowledge and artefacts—leads to a sense of ownership of the intellectual means of that production. That is, makerspaces "democratize access to the discourses of power that accompany becoming a producer of artifacts" (Halverson & Sheridan, 2014, p. 500) while reuniting physical and intellectual labour (Gauntlett, 2011; Kafai & Peppler, 2014).

Study Design

Participants and Project

MakerMinds was designed to blend together the generally accepted principles of makerspace pedagogy (Blikstein, 2013; Halverson & Sheridan, 2014; Sheridan et al., 2014) with the so-called "classical" elements of any mindfulness training program (Flook et al., 2010). The mindfulness content was based in part upon the Mindfulness-Based Stress Reduction training program (MBSR), with the adult-centric language adapted to suit the comprehension levels of Grade 4 students. This was supplemented by close readings of several other well-known mindfulness programs for young people, including the MindUp program (Hawn Foundation, 2011), InnerKids (Flook et al., 2010), and Learning to BREATHE (Broderick & Metz., 2009). In addition, one of the article's authors has first-hand experience with several mindfulness programs, including MBSR.

The program was carried out in the library/makerspace of a public elementary school in the Greater Toronto Area of Ontario, Canada in April and May of 2019. A class of 26 Grade 4 students, aged nine and 10, participated in the program, and 24 of these students agreed to participate in the research study.

Over two months, student-participants engaged in eight "MakerMinds" sessions. Three of these sessions were single periods of 45 minutes. These short sessions were dedicated to mindfulness training, including core content connecting mindfulness to neu-

rophysiology, as well as mindful movement exercises, meditation, and practising new mindfulness tools or techniques. Interspersed with these short sessions were four 90-minute periods. In these double periods, students participated in all of the same curricular elements as in the short "mindfulness-only" sessions. However, the second half of these classes was devoted entirely to making.

In general, students in the MakerMinds program learned what mindfulness is (both as a construct and in relation to human neurophysiology) and how its various techniques can be used to understand and manage thoughts and emotions, reduce stress, and promote overall mental wellness. The core content of the program focused on the three intersecting themes of mindfulness, neurophysiology, and metacognition.

For example, in one lesson called *Why Does My Stomach Hurt?* students learned about their sympathetic and parasympathetic nervous systems. With some basic knowledge about what happens to their bodies in periods of extreme stress and relaxation, this lesson prepared students to recognize their own physical manifestations of stress, to metacognitively connect these sensations to thoughts or events, and to choose the use of a mindfulness tool to manage their physical and emotional reactions. Researchers posit that mindfulness indirectly affects physiological symptoms through a stress buffering system that works, in part, to inhibit stress activity in the prefrontal region of the brain via a top-down regulatory pathway (Creswell & Lindsay, 2014). The *Why Does My Stomach Hurt?* lesson teaches students how and when to use their own regulatory pathways, very much in keeping with scholars who refer to mindfulness as a "mode" (Bishop et al., 2004) to be, in a sense, activated and used at will.

In the "making" sessions, students worked in one of six small groups of four to five students to create physical models of the brain-body processes affecting their mental well-being. This included brains, neurons, spinal cords, and nerves, depending on the core content of the day. Students were free to build their models in whatever manner they wished using anything selected from the buffet of materials provided. In the first making session, each group created a life-sized human cut out as a means of displaying their models. These cut outs (or "buddies" as they came to be called) became more elaborate and creatively decorated as the weeks passed. The final making session was dedicated to integrating simple electrical circuits into the "buddies" using wires, coin batteries, switches, and LEDs. Students were asked to light up any aspects of their models they thought were especially important in understanding mindfulness.

By the end of the program, participants had produced six entirely unique representations of the mindfulness-related physiology they had learned along the way, complete with working switches and lights. In the eighth and final session of MakerMinds, parents, siblings, peers, and other visitors were invited to an open house in the library/makerspace where students shared their models and all the new knowledge they had built together with their peers.

Data and Analysis

As an integrated curriculum of this kind had never before been attempted, this research was entirely exploratory with the aim of understanding ***how*** makerspace pedagogy and mindfulness training interact when carried out in combination, including how this combination impacts student-engagement in mindfulness training, as well as their uptake of mindfulness content.

Our approach was entirely qualitative in nature, adhering to the principles of ethnography in an action research setting (Creswell & Poth, 2017). Data collected included observational data from three different sources: two researchers' field notes and field notes from a non-participant observer hired when the school board turned down requests to video-record the sessions in progress, citing privacy concerns. Weekly interviews with the classroom teacher were conducted, as well as post-program interviews with students and parents. Extensive photographic documentation was collected of the students' artefacts-in-process and reflective journals were kept by one researcher throughout the study. Finally, students completed a weekly reflection journal at the end of each session. Given that "relatively little is known about children and adolescents' subjective experiences with mindfulness training, particularly in school settings" (Maloney et al., 2016, p. 321), the journals served an essential role in facilitating the inclusion of student-participant voices (Himmelstein et al., 2012), an important aspect of ethnographically informed research.

Data were thematically coded using NVIVO 12. Though initial case-nodes were created for "making" and "non-making" sessions, further nodes were created and data assigned only as they were identified through repeated readings of each document. It was through this long and meticulous process that patterns and thematic links were constructed to inform an overall interpretation of the data.

Findings and Analysis

The combination of mindfulness with making produced a program that engaged the vast majority of its participants in both making and mindfulness activities for the full duration of eight sessions. Indeed, all the students in this study reacted positively to MakerMinds overall, and all of them learned to use mindfulness tools on their own in times of stress or difficulty, a central goal of the program. Below, we explore a number of findings related to the interaction of the program's combined pedagogies. Presented thematically, these findings are rooted in students' own words as we relied heavily upon their reflection journals, post-program interviews, and speech captured in class, along with the observations of three researchers and both teacher and parent interviews.

Learning Mindfulness Through Making

In contrast to traditional mindfulness training programs—and indeed traditional forms of schooling—having students *make* physical representations of their learning leveraged the power of constructionism. By externalizing their thinking, students in this program were able to concretize knowledge, make mental connections, identify missing knowledge, and learn from their mistakes. By building "buddies" using a variety of crafting and recycled materials to be shared at the open house, students were building public entities (Papert & Harel, 1991) while also constructing their own knowledge of mindfulness (see Figure 1). A number of examples suggest that this was the case and are discussed below.

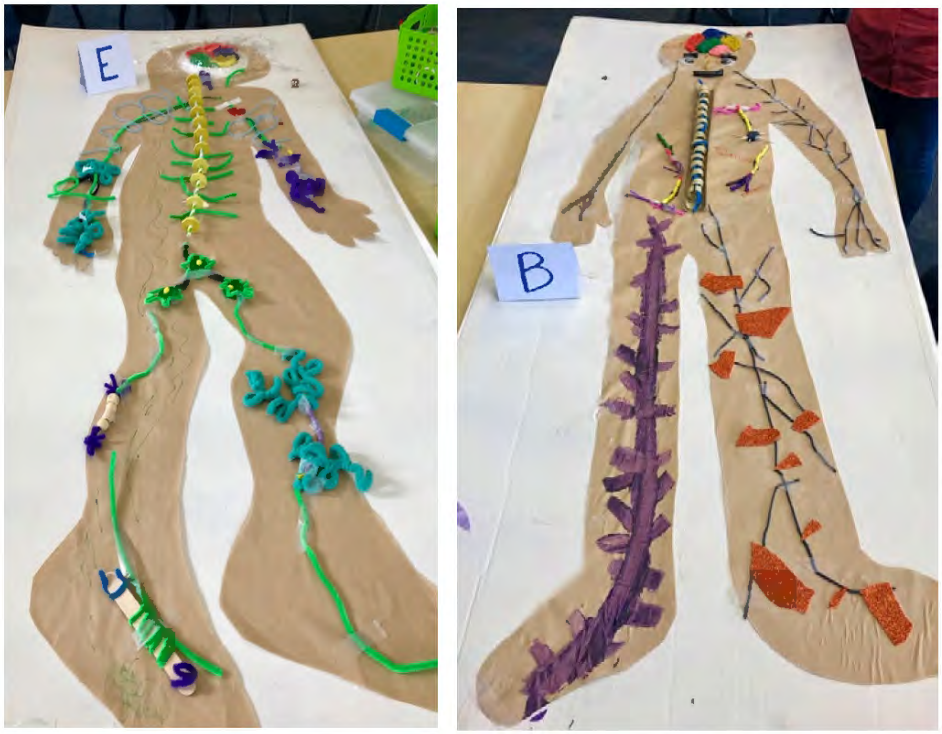
In the first making session, one group "put all the different parts of the brain together and then worked to make realistic creases that they filled with glue and called 'sulki' [*sic*]" (NPO Notes, Session 1[1]). In another making session, researchers noted that students were "using vocabulary from the earlier lesson, like 'dendrites' and 'axon terminal'" to describe their making (CF Notes, Session 3). One student pointed to his work and said, "that's the myelin sheath," while his peer added, "that's the axon terminal…and that is the nucleus" (JEK Notes, Session 3). Decidedly tangible, these "object[s] to think with" (Halverson, 2013; Litts, 2015; Reisberg, 1987) were poked, prodded, and manipulated

1 The lead researcher's field notes are cited using the initials JEK; the program co-facilitator's notes are cited using CF; and the non-participant observer's notes are cited as NPO.

in a way that seemed to help students understand what they were and how they worked. Building the models gave context to the vocabulary they were learning and concretized knowledge that might otherwise have remained entirely cerebral and therefore intangible.

Figure 1

"Objects to Think With": Two of the Groups Show Off Their "Buddies" in Session Seven (May 2019)



This mastery of vocabulary was evident a number of times, including when the classroom teacher asked a group of students to explain what they were making. One student responded,

> I rolled up the plastic and used the yellow pipe cleaners to wrap around it. That's the vagus nerve that carries the message from the stomach. See? It's attached down there where the stomach is and there where the heart is. (JEK Notes, Session 5)

Making scholars argue that physical connections lead to mental connections (Kafai et al., 2012) and that insights arise through the process of production (de Castell, n.d.). In this case, the student physically connected the (yellow pipe cleaner) vagus nerve to the stomach and heart via the (plastic tube) spinal cord in a way that highlighted the importance of the stomach in mindfulness.

In yet another example, a student suggested that connecting the simple electrical circuits was "like the neurons in our body" because "we put the lights where the body parts were and then we connected them together…so it was like your brain sends a message to there" (Mason's Interview[2]). According to makerspace literature, such connections and insights arise from the tactile manipulation of a made object in a way that cannot happen when the learning is strictly intellectual (Halverson, 2013; Papert, 1993). Another student explained it this way: "We built each part of the brain like the pre-frontal cortex and all of those [parts] and then put them together…. Because [we] were putting parts together that gave [us] a better understanding of it" (Max's Interview).

Missing Knowledge and Making Mistakes

Building models also made learning transparent in a way that highlighted gaps in understanding. Non-working features of an external artefact readily revealed "missing knowledge" (Kafai et al., 2012; Kafai & Peppler, 2014). This was most evident in the building of simple electrical circuits and the way these circuits were incorporated into the "buddies." One group, for example, struggled to figure out why a particular switch didn't work like the others. This group had accidentally been given an NC switch (meaning "normally closed"), while all the others were NO ("normally open"). If connected, the NC switch left the LED on all the time and quickly drained a battery. After working on the problem for well over 30 minutes, one particular student "proudly showed" the researchers his solution: he kept the heavily taped circuit intact and turned the LED into a switch by leaving one of its leads slightly disconnected (JEK Notes, Session 8).

In this case—and others like it—students were missing the knowledge of how to complete a circuit and how to fix the problems that arose while working with them. They were thereby immersed in a reflective practice, one that might provoke internal

2 To protect the identities of student-participants, all names have been changed.

questions such as “Why doesn’t this part work?” “What else can I try?” “What else do I know?” In other words, a student might reflect simultaneously upon the work in progress and their own thinking, striving to understand what has been learned and what knowledge is yet needed.

Most of the students were so motivated to achieve functioning lights that they led the way in identifying problems, reflecting on what had and had not worked, and trying again. Students were “tinkering” with the circuits, iteratively exploring them in relation to the materials at hand. This sometimes led to surprising results. One group, for example, had a particularly challenging struggle with electrical tape, described by a student this way:

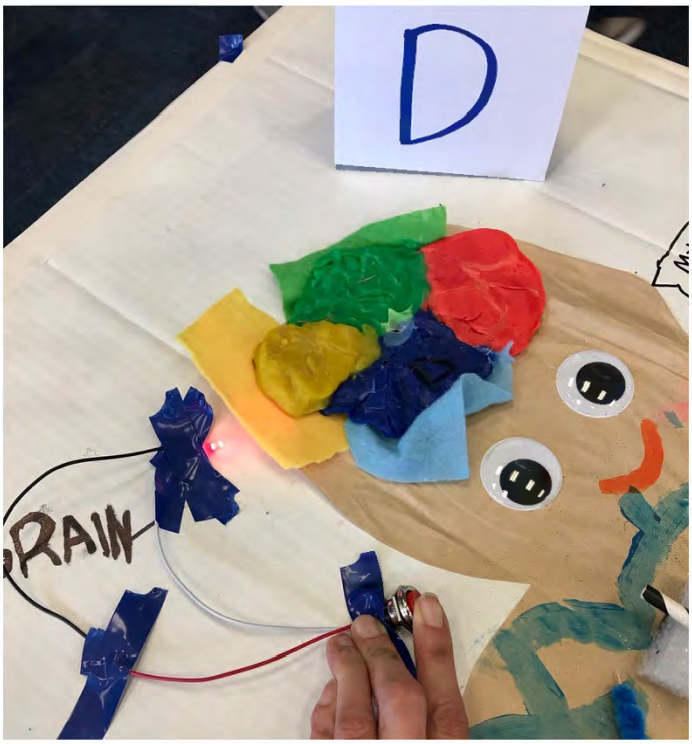
> Well, when we were trying to put the lightbulb underneath [the cardboard], we were having some problems because whenever we put it together it would fall apart and our whole group was getting frustrated and we just decided to put [the circuit] on the top instead and when the open house day came we just moved the light onto the brain so that it would look like the amygdala was flashing so people could see it. (Noelle’s Interview)

Though this group struggled and failed repeatedly to establish a working circuit with all the wires hidden, their eventual decision to attach it firmly to the top of the cardboard had advantages that they chose to view positively (see Figure 2). A number of students in the class ended up using this “buddy” at the open house as a visual example of how their own circuits worked. This is very much in keeping with maker culture, “where failures are celebrated as learning opportunities” (Hughes & Morrison, 2018, p. 370) and where the concept of “productive failure” is essential (Kafai & Fields, 2018, p. 5).

Makerspace pedagogy encourages students to make mistakes as an essential part of the iterative learning process and the students clearly appreciated this freedom. One student said, “sometimes the mistakes actually made something better and newer” (Esther’s Interview), and another wrote in her journal, “our group messed up but we kept on trying and we ended up with a really cool thing” (Noelle’s Journal, Session 3).

Figure 2

Group D's Circuitry Mounted on the Top of the Cardboard, Finally Working and Visible to All (May 2019)



Sharing Knowledge and Feedback

Mindfulness activities are often conducted alone as part of a personal practice. However, mindfulness scholars claim that the prosocial outcomes of mindfulness training, like compassion, empathy, and respect for others, suggest that it is well-suited to being used in social situations (Davidson et al., 2003; Shapiro et al., 1998, 2007). This study's combination of mindfulness training with the social affordances of makerspace pedagogy enabled students to leverage what many scholars refer to as the fundamentally social nature of learning (Gee, 2003; Lave & Wenger, 1991; Vygotsky, 1978; Wenger, 1998).

Indeed, the benefits of collaborative learning were most apparent in the way that students shared their labour, their knowledge, and their feedback throughout the making sessions.

In session three, for example, researchers noted that one group had "decided to [each] make different parts of the neuron and then put it together" afterwards, but they were also "talking to each other throughout the process to work out who was doing what and to announce what they were making and what they were using" (JEK Notes, Session 3). Another group "progressed quickly in making neurons [and] seemed to work well together, each doing parts of one neuron and then bringing them together to make it whole" (CF Notes, Session 3).

Similar scenes played out in every making session. One student explained it this way: "Well, me and the girl that was doing it with me, we did it together…she helped me so…I would make the clay and she would paint it while I was trying to shape the clay" (Braelyn's Interview). Another appreciated that "instead of being by yourself and you had to focus on many things, we could split [the work] up and I could be working on one part of the brain and the others could be working on other parts" (Michael's Interview). In dividing the work this way students were not merely being efficient; they were in fact sharing their knowledge and ideas as they built one final "buddy" per group.

Although this knowledge-sharing occasionally led to accusations of "copying" between groups (JEK Notes, Sessions 5 and 7), there was much more evidence that it was both helpful and appreciated. One group, for example, chose to make three or four different neurons at the same time rather than all contributing to one. Still, they talked as they built, sharing "what materials they were using and how they were making each model" (JEK Notes, Session 3).

Another group was observed "bouncing their ideas off each other and working really closely" as they put together "quite a complex model using layers of clay, some paper, small pompoms, and toothpicks" (JEK Notes, Session 3). Sometimes, this sharing of knowledge meant capitalizing on a group member's particular strengths. For example, one boy became known as "the electrician guy" in his group (JEK Notes, Session 8), another student took charge of the LED in his group (Nick's Interview), and another was appreciated for his skills in art (Nadia's Interview).

Providing feedback to one another was also a key feature of this collaborative approach to learning. This was perhaps clearest when students asked each other for help. At other times, however, unsolicited feedback was provided. One student, for example,

tested the switch on her group's LED and then told her peer with some excitement to turn it "the other way, the other way!" When this girl followed the instructions, the LED lit up and they both shouted, "It works!" (NPO Notes, Session 7).

Feedback like this—both solicited and unsolicited—is considered to be "commonplace and a key driver of learning" in makerspace pedagogy (Sheridan et al., 2014, p. 515). One of the students explained that working collaboratively meant "you have all these neat ideas from everybody in your group and…people come up with new ways that you didn't think about" (Max's Interview). Another student saw the maker groups as able to "expand your ideas" (Esther's Interview), and another "liked that we all contributed our ideas…[and] we helped each other when we were struggling" (Noelle's Journal, Session 6). In each case, students were "leverag[ing] the knowledge in [the] network" of the group rather than attempting to build that knowledge alone (Gee, 2003, p. 189). From a constructionist perspective, the social context "shape[d] the learning trajectory and…[was] a repository from which learners [drew] resources to work out their thinking" (Litts, 2015, p. 40). The examples provided suggest that students' comprehension of mindfulness-related content was indeed positively impacted by the "social context" of making and learning in collaboration with others.

Open House Authenticity

The final session of MakerMinds was devoted entirely to an open house designed as an opportunity for students to share what they had learned about mindfulness (in part) by building their "public entities." In keeping with makerspace pedagogy, sharing artefacts and knowledge with an audience was embedded into the project from the beginning (Halverson, 2012; Sheridan et al., 2014). Many of the students eagerly anticipated this event. On the day, well over half the parents showed up, along with several grandparents, several teachers, the school trustee, and three other Grade 4 classes. The mood in the library/makerspace was celebratory and students were palpably excited to show off their "buddies." Researcher field notes from this session contained many descriptions of students sharing their work with visitors, but two examples stood out. These interactions highlighted just how much some of the students had learned:

> When a guest stopped by to ask questions, "Jacob" and "Michael" talked over each other in their excitement to explain what the amygdala was and

> why it lit up on their "buddy." They quite eloquently explained…what would happen if you saw a bear and the fight, flight, freeze response kicked in, and how you could calm it by using meditation and other tools. They talked about responding to stressful situations instead of just reacting to them. I was amazed at their understanding and I got to watch them explain this several times over the course of the open house. (JEK Notes, Session 8)

> I watched Max explaining his work to a visitor in great detail. That same visitor stopped by afterwards to tell me she couldn't believe how detailed their answers were and how engaged the students were in what they had learned. She referred to Max's explanation and also the way that Marie had talked about neurons, and how their model of the "buddy" had burned his finger and the neurons had passed that message to the brain at 150 m/s and then the brain told the body to move his finger away… (JEK Notes, Session 8)

In all of the ways described above, and in contrast to more traditional approaches to mindfulness training, students in this program built their own knowledge of mindfulness by building physical representations of their learning. In addition to this knowledge-creation, the act of sharing their built artefacts with an audience of teachers, parents, siblings, and peers lent an authenticity to their work that deepened an already powerful learning experience (Halverson, 2013; Sheridan et al., 2014).

Practising Mindfulness while Making

There were many moments during this program when students struggled with putting their models together, with difficult materials, with tools, and especially with electrical connections. And yet they persevered because, in the midst of these struggles, they were able to reflect on their own thoughts and emotions and have some means of control over them. Students were able to shape adaptive responses to stressful experiences, in part because mindfulness facilitates sensitivity to the connections between thoughts and physiological responses (Bishop et al., 2004; Paneduro, 2016; Teper et al., 2013).

This is why so much of the program's mindfulness content was focused on connecting physiological sensations with emotions as a way of helping students recognize when they might need to use a mindfulness tool. In an early session, students described

worry and frustration as "clenched teeth," "butterflies," and "clenched monster toes" (NPO Notes, Session 2), as well as "squinting eyes, sweating, and shaking" (CF Notes, Session 2). When they experienced sensations like these in their own bodies, they learned to see them as indications that a mindfulness tool might help them calm down and/or let go of unhelpful and stressful thoughts.

Like the reflectiveness involved in making, mindfulness is fundamentally about reflecting on the workings of one's own mind. Mindfulness scholars hold that cultivating an awareness of thoughts and emotions generates a powerful ability to reframe those thoughts and regulate those emotions (Bishop et al., 2004; Corcoran et al., 2010; Grecucci et al., 2015; Shapiro et al., 2014; Teasdale, 1999; Teasdale et al., 2002). This central concept in mindfulness was best learned experientially (Gouda et al., 2016) and the making sessions provided plenty of opportunities for students to put their mindfulness tools to work.

Putting Mindfulness Tools to Work

Toward the final few sessions of the program, a number of students clearly recognized a need for the mindfulness tools and used them to persist through difficult moments in making. In session five, one researcher noted that a student "was trying to get the backing off the double-sided tape." She wrote that "he was getting frustrated because it was tricky and he said, 'square breathing' out loud." Then she added in parentheses: "He noticed he needed to use a tool!" (CF Notes, Session 5). It was perhaps because the students were never explicitly directed to use mindfulness tools during the making sessions that it was so interesting to see it happen.

Another student explained in his post-program interview that learning mindfulness tools helped him to "never [give] up again" when building his challenging 3D puzzles at home. He said that he learned "to be patient in making" by "doing some mindfulness to get through it" (Jacob's Interview). A second student talked about using "square breathing" when "it got a little frustrating" that the light "kept coming loose off the battery" (Michael's Interview). A third wrote that she had learned to use mindfulness to calm herself down when she got "frustrated about the light" (Stefie's Journal, Session 7). Yet another student wrote after a making session, "I can feel my emotions and use mindfulness tools to calm me down" (Marie's Journal, Session 3).

Sometimes, the need to use mindfulness tools was connected more to dealing with peers than with problems in their work. Following session five, for example, one

boy wrote that he "learned the [five] senses helped me when 'Jacob' was talking" (Tyler's Journal, Session 5). Another student struggled with some of his fellow group members. He said, "They were messing around with the light switch that I had just finished and I couldn't get it back so I did square breathing" (Joseph's Interview).

By generating stressful situations like these, the makerspace pedagogy in this program provided students with immediate and meaningful opportunities to practise their mindfulness training. In all of the above cases, students exhibited what mindfulness researcher Kabat-Zinn (2013) refers to as a central lesson of mindfulness: the "ability to be aware with intentionality and modulate accordingly the actions we choose to take" so as to cultivate "equanimity in the face of stressful circumstances" (Kabat-Zinn, 2013, p. 315).

Persistence through Making

Mindfulness scholarship claims that students' awareness of their ability to mindfully manage thoughts and emotions helps them to develop a sense of their own agency (Larson, 2011). Indeed, there is a great deal of evidence in the data to show that students reflected on their ability to manage difficult situations by using mindfulness tools. In one of 95 similar examples, a student wrote, "I learned that many of the mindfulness techniques helped in a stressful situation for me like running track and field. I used square breathing to pace myself" (Marie's Journal, Session 5).

The makerspace pedagogy supported and reinforced these lessons. Through its iterative nature, students developed an agentic awareness of their ability to solve the problems inherent in making, many of which arose through the challenges of working with the materials provided. One student, for example, got paint in her hair (NPO Notes, Session 7); another cut her finger while using a tape dispenser (NPO Notes, Session 1). A lack of stickiness on some electrical tape caused yet another group to struggle throughout session seven to produce a working circuit (JEK Notes, Session 7). As frustrating as these and many other similar problems were, students learned to accept them as part of the building process.

These frustrations arose through the "trial and error" of making. Managing them required a resourcefulness "propelled through a maker's curiosity" (Peppler et al., 2016, n.p.). In one group, for example, students had trouble with the brain they built. A group member explained, "The first day we started the brain, but then in the box it broke so

on the last day we made a whole new brain." In another group, it was the spinal cord that caused some trouble because "the little parts of the spine kept snapping." This was "kind of worrisome," said a group member, but in the end "we just glued them together" (Ethan's Interview).

Students persisted through such difficulties in order to complete their maker projects and a number of them reflected on this important aspect of making. Referring to her group's lengthy struggles with the circuit, a student wrote, "We worked together when we were struggling and even though it didn't work out how we wanted it to, we still had fun" (Noelle's Journal, Session 7). Another student wrote, "I liked how nobody wanted to give up when our circuit wasn't working. The team's determination and perseverance was great!" (Esther's Journal, Session 7). And yet another wrote, "I persevere in tough moments" (Kristin's Journal, Session 6).

Figure 3

Making Together while Sharing Labour, Knowledge, and Feedback in Session Three (April 2019)

Conclusion

Merging mindfulness training with makerspace pedagogy produced a program that supported students in mindfulness content and encouraged their application of mindfulness tools as needed in their daily lives. The vast majority of students remained engaged throughout the eight sessions and all of them gained experience in using mindfulness tools to support their own mental well-being and to persevere through difficult moments. At the same time, the making sessions were not just a means of learning about mindfulness, but also encouraged students to solve difficult problems, to work with electrical circuits, and to persevere through the challenges inherent in making.

This exploratory study demonstrated how mindfulness and makerspace pedagogies interact when carried out in a single curricular intervention. In particular, the makerspace pedagogy encouraged students to externalize their understanding of mindfulness as it developed over the course of eight weeks. This externalization helped students to concretize their knowledge, make mental connections, master some of the vocabulary related to bodily processes and mindfulness, identify and fill in gaps in their understanding, and learn from their mistakes. The challenges inherent in making also deepened students' experiential understanding of mindfulness by creating stressful situations that they learned to navigate using their newly acquired mindfulness tools. Working through these challenges reinforced students' understanding of themselves as able to persist through difficulties, also a key aspect of mindfulness training. We argue that the social aspects of makerspace pedagogy facilitated this learning by encouraging students to share their labour, their knowledge, and their feedback. Finally, the open house gave students the motivating and validating opportunity to share their knowledge of mindfulness with an external audience.

In sum, the makerspace activities worked to hold students' attention and deeply engage them in mindfulness content, impacting their conceptual and experiential understanding of mindfulness and their ability to apply that understanding in their daily lives. In the end, the combined pedagogies developed students' self-awareness as both problem-solving makers and nascent mindfulness practitioners with the skills to manage their own emotions better and persist through demanding and novel learning activities.

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