Maker Pedagogy and Science Teacher Education

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Science education is experiencing a bit of a renaissance, it seems, thanks in part to widespread interest in so-called science, technology, engineering and mathematics (STEM) education. Longstanding debates around issues in science curriculum studies have taken on new senses of urgency, particularly as science curricula in many parts of the world are in the process of reform. In North America, the recently published *Framework for K-12 Science Education* (National Research Council, 2012), in the United States and the 2012 special issue of the prestigious natural science journal *Science* entitled “Grand Challenges in Science Education” highlight the urgency associated with reform in science education and, by extension, science teacher education. The concern seems to extend outside the realm of those explicitly connected to education: A recent

Journal of the Canadian Association for Curriculum Studies
Volume 13 Number 1 2015

report prepared for the Canadian Council of Chief Executives argues, in part, that "the proportion of [Canadian] students in STEM programs is weak, especially at the postgraduate level" (Orpwood, Schmidt, & Jun, 2012, p. 3). Pessimistically, we might say that STEM teacher education is merely repackaging old (and not particularly successful) curriculum ideas, such as science literacy, in slightly different ways. Breiner, Harkness, Johnson, and Koehler (2012) argued that STEM is an incoherent concept that means very different things to different stakeholders. More optimistically, we might suggest that STEM makes explicit room for a reframing of the curricula of science teacher education by acknowledging the symbiotic relationship that exists between science and technology, as opposed to reductionist views of technology to applied science. In this article, we will use the maker movement (Anderson, 2012) as a catalyst to reveal both some perennial challenges of and potential ways forward for curriculum studies of science and technology teacher education. In particular, we offer a concept we refer to *maker pedagogy*. Maker pedagogy is an approach to working with teacher candidates drawing from principles in the maker movement that, in our view represents a potentially useful way forward in engaging teacher candidates in thinking about curriculum and working with students.

Our ideas about maker pedagogy are developed from the more general ideas about *making*. Making is a process that people engage in to design, create, and develop things that are of value and use to them personally or for their community. The recent popular (and sometimes commercial) maker movement is rooted in *making* and traces its lineage from a variety of historical do-it-yourself precedents, including ancient traditions of arts and crafts fairs, tinkering and inventing using analog technologies, and ethical hacking and programing with digital technologies. So-called "Maker Spaces" often function as co-ops that allow people to come together to build things, share expensive tools, and learn skills from one another. Many self-identified *makers* link their work to broader themes of environmental consciousness and sustainability, arguing that simple hacks and modifications can breathe new life into "last-year's model" of a digital device. The broader cultural phenomenon of the maker movement happens to coincide with the recent enthusiasm for science, technology, engineering, and mathematics (STEM) education and a concurrent examination of the education of future science teachers. This enthusiasm, as we shall later see, is grounded at least in part in policy that equates science education with economic progress and nationalism. STEM, and the many ideas that it calls attention to, is at the forefront of many future science teachers and teacher educators' minds. For some, STEM seems to represent a call for integration between related subjects. For others, STEM is an approach to science education informed by research.

We would understand if the reader's initial reaction to the idea of *maker pedagogy* is a concern that we are arguing for "one more thing" on the rather large tapestry of science curriculum theory. Since the launch of Sputnik, science education has been subject to a fairly continuous wave of new curricular ideas: science literacy, scientific literacy, the nature of science (NOS), and inquiry to name a few. We are mindful of a comment Selwyn (2011) makes about research in education and technology: It is important to ask "What is new?" about a new idea. We are also mindful of Christou and DeLuca's (2013) five concerns about the field of curriculum studies, published in this very journal, when we forward the idea of maker pedagogy to the field of science teacher education. For example, one might wonder if this is yet another piece of jargon, or if we have failed to consider historical precedents for how we have learned from and with technology in formal and informal education. We will return to these ideas later in the paper.

The enthusiastic and sometimes competing discourse around STEM and/or science education is occurring within a larger backdrop of popular and public discourse on teacher education. It is not difficult to locate articles that paint a dim view of the efficacy, the utility, and the structure of formal teacher education programs. Hirschkorn and Sears (2015) argue that some of these difficulties in teacher education come as early as the admissions process, which needs to be reframed to serve a pedagogical function in addition to its gatekeeping function. Falkenberg and Smits' (2010) two volume, edited book devoted to the practicum in Canada explores the ongoing complexity of the field experience, revealing that we are still grappling with many questions posted at least 100 years ago, as outlined in an article by Vick (2006). The pan-Canadian scholarship that has come out of regular working conferences hosted by the Canadian Association for Teacher Education reveals the ongoing challenges associated with institutional reform mandated from within and, on occasion, from external stakeholders such as provincial ministries. Canadian Teacher Education seems to be undergoing continuous reform, of varying scopes (Falkenberg & Smits, 2008; Falkenberg & Smits, 2010; Thomas, 2013; Thomas & Hirschkorn, 2015).

It is well-documented that reform in teacher education is difficult (Bush, 1987; Cole, 1999). One reason for this difficulty is offered by Sarason (1996), who commented that most of us approach school with an inherent insider perspective, since we have all been to schools ourselves. Most people who teach in Faculties of Education, particularly in teacher education programs, have been through similar programs at some point in their careers and so they have the insider status that Sarason mentions. Darling-Hammond's (2006) case studies of teacher education programs offers three problems of learning to teach: The problem of the apprenticeship of observation, first named by Lortie (1975), the problem of enactment, first named by Kennedy (1999), and the problem of complexity. Russell (2008) posited that the second and third problems are in fact consequences of the effects of the apprenticeship of observation. By the time they arrive at a teacher education program, teacher candidates have witnessed thousands of hours of teaching with little access to the reasons why teachers behave the way they do. Candidates thus find it difficult to enact their vision of teaching during practicum or that they often comment that they were unaware of the complexity of the work of teachers.

Future science teachers thus come with a wealth of ideas developed from their apprenticeships of observation in K-12 and post-secondary school (Bullock, 2011). They tend to believe that science class should involve labs, that it is content-rich, and that students need to become expert problem solvers. The role that technology might play in science class is ambiguous and we remain unconvinced that the majority of future science teachers see themselves as technology teachers as well, despite the curricular trend of moving technology outcomes into the science curriculum. In this paper we posit that ideas from the maker movement, framed as *maker pedagogy*, might help future science teachers to reframe their identity as technology educators while simultaneously helping them to understand their role as *makers* of curriculum, rather than as transmitters of information. We begin with a brief overview of some features of the maker movement before reviewing two prominent trends in curriculum studies of science education over the last few decades: The enthusiasm for *science literacy* and *STEM*. We will then examine some of the ideas from maker movement in light of suggesting a productive line of thought for curriculum studies in science and technology teacher education. We conclude with by examining our nascent ideas in light of Christou and DeLuca's (2013) five concerns about the field of curriculum studies (jargon, contemporaneity, grandiosity, discursive balkanization, and methodological insufficiency), which give us a way of navigating forward in our investigation. Ultimately, we argue that the maker movement is a good example of the kind of social phenomenon that Christou and DeLuca suggest for "engaging curriculum as a social inquiry, not as the subject of inquiry by a select few" (p. 13) and that curriculum studies of science and technology teacher education would benefit from robust consideration of the idea of *maker pedagogy*.

The Maker Movement

This section gives a brief overview of the do-it-yourself and maker cultures as they relate to the maker movement. To our knowledge, there has not been an academic study of maker culture and so this section has been created largely from popular accounts of groups and individuals that self-identify as "makers." Anderson (2012), a well-known maker, argues that the maker movement has the following three "transformative" characteristics:

1. The use of "digital desktop tools to create designs for new products" ("digital DIY").
2. "A cultural norm to share those designs and collaborate with others in online communities."
3. "The use of a common design file standards that allow anyone, if they desire, to send their designs to commercial manufacturing services." (p. 21)

It is important to note that Anderson's characteristics are quite focussed on the entrepreneurial and industrial fabrication parts of the movement. Although these concepts are undoubtedly part of the movement, we adopt a more holistic definition. The maker movement and is simply defined as a large-scale, loosely organized culture where people who self-identify as makers come together to make technological artefacts. It is important to note that technologies need not be purely digital. The motivations of members of the movement are often to design, create, ethically hack, and adapt technologies. The maker movement shares much in common with a long history of do-it-yourself (DIY) culture.

DIY Culture

Do-it-Yourself (DIY) is a culture of autonomy wherein the designer or creator relies on the self and/or their community to complete self-identified project(s) of interest. Internationally, the DIY movement peeked largely during the 1990s with the global impetus for the movement ascribed to many agendas including political, musical, artistic, and dance. The DIY zeitgeist propelled ideals of co-operation, access to tool and technologies, the differentiation of art, resistance against industrialization and mass production, all the way to the creation and admiration of objects that were developed in good-taste and for personal autonomy and self-fulfillment (Morozov, 2014). Lupton embellishes these thoughts in her book suggesting that "around the world, people are making things themselves in order to save money, to customize goods to suit their exact needs and interests, and to feel less dependent on the corporations that manufacture and distribute most of the products and media we consume. On top of these practical and political motivations is the pleasure that comes from developing an idea, making it physically real, and sharing it with other people" (2006, p. 14).

DIY culture is grounded in an ethic that requires an individual or a group to identify and make assessments of skills and knowledge that are essential to task performance of the project at hand. The individual is placed at the helm of seeking out the requisite skills in order to successfully complete their intended project. Projects span from personal through to work including arts and crafts, home and landscaping improvement, vehicle repair, woodworking, metal work and other craftsmanship.

Those who practice and champion the DIY culture proclaim the zeitgeist is the empowerment and agency of the individual or a community to do things in the physical world with others. The punk culture and music arena, circa 1970 (Triggs, 2006), perhaps demonstrated some of the earliest genuine DIY spirit through the reuse and remix of existing societal practices that fostered less reliance on corporate systems. Extensions of the DIY punk culture are witnessed in self-published zines of the feminist movement, and in Edupunk where the attitude towards education is: shared learning relationships, self-assessment, thinking and learning relevant to your situation, while being reactionary towards for-profit learning models (Kamenetz, 2009).

Maker Culture

Maker culture is the contemporary expansion of the DIY culture into the realms of technology, particularly technologies that make use of electric circuits and computer software. Traditional DIY projects are grandfathered, however, developments and advances in technology, computing software and hardware, and internet capabilities and speeds have increased accessibility and reduced the cost of doing-it-yourself. As such, the flavour of maker projects typically focus on electronics, robotics, and 3D printing to name a few. The ethic of the DIY culture to learn new skills also carries into the maker culture but where the extensions arise in the spirit of re-using and adapting (e.g.: materials, resources, and programming), remixing (e.g.: networking and sharing in hackerspaces, interdisciplinary collaboration), and open-source access (e.g.: publishing design, blueprints, or prototypes). The maker culture may carry with it a certain enthusiasm for innovation and change and this shifts the do-it-yourself-er to a maker, as someone who designs and creates. Taking leadership from the DIY culture wherein the ethos is connected to tactile activities, enthusiasts attribute the maker movement to an increase in the desire for connection to the physical world (Swan, 2014) and community.

This draws the attention of educators who witness students' disconnect in STEM disciplines, particularly as student do not typically have the opportunity to make things in the classroom . Drawing from the re-use and remix ethic of the maker culture, some tenets that may inform education include physicality, participatory action, collaboration, and an ethos of sharing using networked approaches.

Maker Movement

The culture of making received increased attention internationally and grew into the maker movement, a culture that has an artisan spirit mixed with experimental play (Honey & Kanter, 2013). The focus of the maker movement tends to be an effort to re-use and repair, often in opposition to consumerism. In 2005, Dale Doughtery coined the term 'Maker

Movement' to support the growing maker culture and also in 2005, O'Reilly Media started Make Magazine that highlighted STEM projects.

The maker movement embraces its DIY heritage and makers, who are often also referred to as ethical hackers (and tinkers who enjoy messing-about), to create a community of people with shared interests, varied skill and knowledge levels, who participate in diverse projects. The maker movement supports makers in the democratization of tools and information (Hatch, 2014) by increasing access and reducing exclusivity. This is done through hackerspaces, machine shops, Fab Labs and various maker spaces (e.g. TechShop, MIT Hobby Shop) where people can share tools, ideas, and skillsets (Kalish, 2010). An ethos of the maker movement may be articulated as creating, developing, and playing with technology through ethical principles such as tinkering and hacking. Hatch (2014) notes in his book, the Maker Movement Manifesto, that tooling-up (in terms of electronics such as littelBits, microcontrollers such as the Ardunio and Raspberry Pi, drones, and 3-dimensional printers) is critical to the growth of the Maker Movement. In maker spaces, it is apparent that "learning is fundamental to making" (Hatch, 2014, p. 21). Making is a participatory activity that draws the whole body of the maker into the creation of the project and the resulting artefact(s) represent the creative process of design, social interaction, and ethos of sharing inherent in the personal and collective learning process.

Curricular Perspectives of Science and Technology Teacher Education

Science education occupies a somewhat unique space in the curriculum of K-12 schools, in that few seem to question its place as a required subject for most of schooling. Technology education, on the other hand, has been essentially removed from the list of required subject experiences for students across Canada. Where technology programs do exist – and there are fewer and fewer of these – technology courses tend to be taken as electives. Although few people would argue that there is some link between the disciplines of science and technology, science seems to have won a continuing place in contemporary schools, whereas technology has not fared as well. Current science curricula fail to frame the relationship between science and technology as a symbiotic relationship and thus fail to understand that technology education creates a space for science education, and vice-versa.

The situation is indeed curious, particularly when the justification for science education has often been framed in nationalistic terms – pride in the scientific achievements of one's country and the economic benefit produced by those achievements have driven two of the main curriculum pushes in science education over the past few decades. *Science literacy* seems like a benign and easily agreed upon goal for science education until one considered its genesis and early history. The term was unleashed in Hurd (1958), shortly after the Soviet Union's successful launch of *Sputnik*. Gripped in the fear that this Soviet satellite was, at the very least, a symbol of Soviet scientific superiority, many Western authorities called for reforms to the elementary, secondary, and post-secondary science curricula:

> Even the casual observer recognizes that science with its applications in technology has become the most characteristic feature of modern society. Attempts to define human values, to understand the social, economic and political problems of our times, or to validate educational objectives without a consideration of modern science are unrealistic. More than a casual acquaintance with scientific forces and phenomena is essential for effective citizenship today. Science instruction can no longer be regarded as an intellectual luxury for the select few. If education is regarded as a sharing of the experiences of the culture, then science must have a significant place in the modern curriculum from the first through the twelfth grade. (p. 13)

It is clear that Hurd believed that science literacy (here equated with the results of rigorous science instruction) was an important goal for elementary and post-secondary schools, both for reasons of tuning in to "culture" and for the economic and political success of the United States. He goes on to say: "There is a concern about the next generation's ability to continue the accelerated momentum of science. The question has been raised whether high school graduates even know the meaning of science" (p. 14). This is another common refrain around science literacy: Science literacy should be made a more essential part of school because it is clear that current students do not know enough about science. We have yet to read a piece from any era or context that claims students know enough about any given subject in school. The current generation, it seems, always falls below our expectations.

It is an interesting problem for educationists when a term for research is first defined in rhetoric. Perhaps it is not surprising that, by the early 1980s, Doug Roberts noted that the term had ceased to have any useful meaning because it had been defined in so many different ways (Roberts, 1983). Writing nearly three decades later in the first edition of the handbook on science education, Roberts (2007) opined:

> This diverse literature [of science education] can be better understood if one comes to grips with a continuing political and intellectual tension that has always been inherent in science education itself. I refer to the role of two legitimate but potentially conflicting curriculum sources: science subject matter itself and situations in which science can legitimately be seen to play a role in other human affairs. (p. 729)

For Roberts, these curricular tensions lead to two visions of science education and science literacy. Vision I is more about being literate about the canon of scientific knowledge and Vision II is more about "science-related situations in which considerations other than science have an important place at the table" (p. 729). In more recent work, Roberts argues that Vision I is *science literacy* (i.e. developing foundational knowledge of science), whereas Vision II is *scientific literacy*, and that the latter "is aligned with such movements as environmental education; science, technology, and society (STS), science, technology, society, and the environment (STSE), socio-scientific issues (SSI)" (Roberts & Bybee, 2014, p. 546) and anything else attempting to link Vision I with broader societal concerns.

If science literacy has ended up a bit of a confusing mess in science education, then one might hold out little hope for the ultimate fate of science, technology, engineering, and mathematics (STEM) education. STEM, like science literacy before it, was created by a policy maker to encourage curricular reform. According to Christenson (2011) Judith Ramaley, former director of the National Science Foundation's education and human resources division, believed that science and mathematics were "bookends" to technology and engineering:

> Science and math are critical to a basic understanding of the universe, while engineering and technology are means for people to interact with the universe. STEM weaves those elements of human action and understanding into all aspects of education.

When one looks at the prevalence of the component STEM disciplines in school, it would seem that the "bookend" disciplines occupy more shelf space than the books. Breiner et al. (2012) summarize much of the problem in a fine article that explores the competing, sometimes conflicting, messages associated with STEM. They argue that the term STEM is frequently used for purposes as diverse as calling for integration between the four component disciplines, recruiting people to take one of the four component disciplines in school, and as a label for using "new" active-learning approaches to science education. STEM, like science literacy before it, is a confusing curricular place.

Towards a Maker Pedagogy

The maker movement phenomenon provides some interesting possibilities for reframing what it means to learn to teach science in a teacher education program. We accept the assertion that one of the most critical challenges facing teacher candidates' learning to teach is the effects of their apprenticeships of observation. It follows that we must consider how teacher candidates' prior experiences as science learners affect their initial views on how to teach science. We argue some cues from the maker movement can serve as catalysts toward an articulation of what we refer to as maker pedagogy, an orientation to curriculum that positions teacher candidates explicitly as makers of things.

Schools are, in general, not places where students get to make things after the early grades. With the exception of visual arts courses and the smattering of technology courses that exist, most students are not positioned as makers of things by the K-12 curriculum. They are sometimes explicitly taught how to *use* devices, such as graphing calculators or computers, in any number of courses. Little attention seems to be paid to the curricular possibilities of asking students to design, create, adapt, or ethically hack (take apart for purposes of understanding) technological devices. Science teacher candidates, by and large, are products of this K-12 system regardless of their undergraduate degrees.

One of the prevalent tenets of maker pedagogy is making technological artefacts through hands-on practice. An application of declarative scientific knowledge to accessible tools and technologies encourages an enhanced understanding of the symbiotic relationship between science and technology. This brings creativity and innovation to the front and centre for the maker while they learn by making. One possibility for extending the making experience is to encourage a metacognitive discussion of where and how various projects may transfer in diverse teaching context. We believe that these sorts of discussions may further inspire a symbiotic approach to learning design and inspire the teacher candidate as the maker of curriculum.

The ethos of learning a maker culture may also inform science teacher education via establishing a space to learn and open conversation about how making enables an understanding of the relationship between teaching about science and teaching about technology. Teacher education programs can provide opportunities to enact these approaches with teacher candidates by facilitating participation in maker spaces. The spaces are both physical meeting areas and avenues for developing community. They should facilitate questions and inquiry. They should encourage a distribution of expertise. They should encourage participatory action that follows in quick succession to the demonstration of a technological artefact.

These cues provide possible principles for working within a maker pedagogy orientation wherein the learner is bridged into an epistemology that fosters learning by making something. Maker pedagogy is an approach that utilizes the principles of *ethical* ***hacking*** (i.e., deconstructing existing technology for the purpose of creating knowledge), ***adapting*** (i.e., the freedom to use a technology for new purposes), ***designing*** (i.e., selecting components and ideas to solve problems), and ***creating*** (i.e., archiving contextual knowledge obtained through engaging in the process of making, as well as the actual tangible products) as part of an overall way of working with those interested in learning about science and technology. It is possible that these principles re-shape a notion of what is means to learn to teach by encouraging the maker within each one of us.

Conclusions

We propose that the act of making something can provide science teacher candidates with a metaphorical compass for thinking of themselves as makers of curriculum. It is unlikely that science teacher candidates give much pause to consider curriculum as *currere* (Pinar, 1975). Engaging in maker projects might stimulate the kinds of autobiographical conversations that Pinar envisioned. Teacher candidates may be prompted to consider their identities as makers of things through making approaches. It is one thing for a curriculum theorist to argue that teacher candidates, like all teachers, are makers of curriculum. It is another thing for teacher candidates to see themselves that way; most are likely to view the curriculum as the government document that tells them the content they must "deliver."

Although we have presented a curriculum of making as a possible antidote to the rather unfocussed dialogue around STEM teacher education, we are also mindful of the fact that we are proposing yet another approach to curriculum studies in science and technology teacher education. As a litmus test for the potential value and pitfalls of introducing a curriculum of making into a consideration of STEM teacher education, we examine maker pedagogy in light of Christou and DeLuca's (2013) five concerns about the field of curriculum studies:

Jargon

Jargon is specialized language that creates both what sociologist Willard Waller would call a "we-feeling" in a particular culture and an often intimidating barrier of entry for those who are not members of that culture. Maker pedagogy, grounded in the Maker Movement, certainly contains a share of jargon: Members of the community and websites are quick to use terms such as Arduino, 3D-printing, microcontrollers, and Raspberry Pi to talk about their work. Entering the Maker Movement can thus seem intimidating for those who do not already possess specialized technical knowledge. Indeed, the terms maker and maker movement might themselves be deemed jargon, particularly in light of the dismal history of curriculum reform in science education. A critic might do well to ask if making is merely the next piece of jargon in a list including science literacy, inquiry, STEM and its arts-infused offspring, STEAM.

Contemporaneity

The movement around so-called 21st century skills brings an illusion of contemporaneity to Maker pedagogy. There is no shortage of slogans advising that learners need to have a particular, novel, set of skills that equips them to deal with the new century and its associated challenges. This line of reasoning is often followed up with claims that teacher education needs to prepare teachers who are capable of teaching K-12 students these 21st century skills. Maker pedagogy might easily fall into the trap of claiming that it is something new, created in the crucible of a new wave of desirable skills. The fact that humans have been making things for as long as we have existed – indeed, some would argue that our use of tools is part of what makes us uniquely human – renders claims of contemporaneity somewhat spurious.

Grandiosity

We worry about explicit or implicit claims that adopting a maker pedagogy will be a panacea for all that is problematic in science and technology teacher education. The idea of some science and technology teachers claiming a "we-feeling" around being makers in order to differentiate themselves from those who do not identify in that way is alarming. To our knowledge, there is a paucity of evidence supporting what we refer to as maker pedagogy. A pedagogy of making requires considerable conceptual work as well, the tools of philosophy are well-suited to examine how maker pedagogy might contribute to the education of teachers and their future students. It remains on the level of an interesting idea that requires further study, a bold Popperian conjecture that has not yet been refuted. We hope our future conceptual and empirical research sheds light on these ideas. In a related concern, the industry that has developed around capital-m Making risks claims to grandiosity. We are sceptical that buying some pre-existing kits will provide the appropriate level of support required to develop a sophisticated understanding of maker pedagogy.

Discursive balkanization

It is safe to assume that both education and educational research often suffers from insular practices between disciplines and sub-disciplines that could be engaged in a more productive discourse. One wonders why the math teacher and science teacher find it hard to get together to talk about what they hope students learn about creating graphs; so too does one wonder why educational psychologists and philosophers find it hard to discuss what teacher candidates should be learning in a teacher education program. It is a longstanding problem that science and technology courses tend not to be a coherent part of a K-12 experience; to the point where technology is treated like a ghostly apparition that is magically attached to, and occurs as a result of, science education (Bullock, 2013). We need to be cautious about the possibility that introducing maker pedagogy may further obfuscate science and technology teacher education into a sub-group of "maker teachers" that do not engage with broader discussions in science and technology education.

Methodological insufficiency

The Maker Movement, in its current form, has been around for about ten years. Anderson (2012) links the beginning of this most recent movement with the development of small-scale production of technological devices. It is hard to avoid the overall enthusiasm for the maker movement in the zeitgeist: Makers tend to self-identify with somewhat aaheroic roles such as tinkerers, environmentalists, and activists within broader concepts of social consciousness such as anti-consumerism and collective organization. Despite widespread enthusiasm for making, Maker Faires, and the Maker Movement (and their associated industries), there seems to be very little research of a conceptual or empirical nature into the Maker Movement. In preparing this article, we were frequently struck by how difficult it is to find scholarly sources on this topic.

Left to its own devices as a part of the zeitgeist, the implications of the maker movement for K-12 schooling and science and technology teacher education risks all five of the traps identified by Christou and Deluca (2013). What, then, is to be done? We believe that Christou and Deluca's final point is particularly relevant to finding a way forward. If maker pedagogy, grounded in some of the principles of the maker movement, is indeed a productive way forward to science teacher education then we require methodological clarity. We must not obfuscate the term "maker" as another piece of educational jargon. We believe that attending to the history and philosophy of technology, going at least as far back as the beginning of mass schooling in the West, will help us consider issues relevant to maker pedagogy. For example, it will be worth examining the reasons why some mechanical arts were framed as "trades" and the others were framed as "crafts" at the outset of schooling. We also believe that ethnography, with its focus on understanding culture, and self-study, with its emphasis on understanding self-in-relation to practice, and related anthropological approaches to educational research offer productive empirical techniques for developing an understanding of maker pedagogy.

Teacher educators cannot rely on candidates' past experiences in K-12 schooling as a foundation for thinking about the importance of creating physical objects. Schools, in general, are not places where children make things past a certain age. As children go through school, they become less and less likely to make a technological artefact. The maker movement provides some interesting possibilities for re-conceptualizing what it means to learn to teach. If we want future science teachers to think about the possibilities of making things with their students and to see themselves as makers of curriculum, we need to find ways to provide meaningful opportunities for them to make things in teacher education curriculum courses. We believe that a conceptual and empirical exploration of the maker movement could serve as catalysts toward an articulation of what we refer to as *maker pedagogy*, an orientation to curriculum studies that positions science teacher candidates explicitly as makers of things.

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