

2016

## Online “Maker” Modules to Support Production Pedagogies in Education

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### Recommended Citation

Hughes, J., Fridman, L., & Morrison, L. (2016, November 2-6). Online “Maker” Modules to Support Production Pedagogies in Education. Paper presented at the *Higher Education in Transformation Symposium, Oshawa, Ontario, Canada*. Retrieved from [hyperlink]

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# ONLINE “MAKER” MODULES

Online “Maker” Modules to Support Production Pedagogies in Education

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Presented at the Higher Education in Transformation Symposium

November 2 - 4, 2016 in Oshawa, Ontario, Canada

### Abstract

Our research study examines the use of online maker modules (developed by our research team) on the learning process for, and professional development of, graduate M.Ed. and M.A. students in a faculty of education in Ontario, Canada. The research draws on the practice of critical making with both digital and real-world artefacts as a vehicle for collaborative knowledge-sharing and generation, deep learning and meaningful engagement with one’s local and global communities. The students engaged in all five online maker modules as part of a graduate-level course and this paper offers insight into the experiences of two of these students -- how the modules impacted their learning process, professional development and their willingness to adopt an inquiry and/or production (maker) pedagogy in their own teaching and learning environments.

*Keywords:* online, maker, modules, professional development, graduate, students, artefacts, collaborative, pedagogy

## Online “Maker” Modules to Support Production Pedagogies in Education

### **Introduction**

A “makerspace” is a communal space where individuals come together to tinker, design, play and create. This space relies on what is called “production” or “maker” pedagogies, which include student-centered approaches to learning such as: constructionist, constructivist, inquiry-based and problem-based learning. Our lab combines literacy and the arts with science, technology, engineering, and mathematics (STEAM) in ways that encourage the discovery, design, and development of creative ideas and artifacts. In our makerspace, maker pedagogies are investigated and developed with the goal of inspiring and promoting new approaches to traditional curricula and pedagogies in Ontario education. This non-traditional approach that facilitates exploration, expression and exposition (Tulley, 2011), encourages students to more thoroughly engage with content, inspires deeper learning, creates connections to real-world problems, and builds collaboration, problem solving, communication and critical thinking skills.

Community makerspaces are becoming a widespread phenomenon; however, these “DIY” models for encouraging teachers and students to become designers and producers of the materials and resources upon which they depend (de Castell, Droumeva & Jenson, 2014) have not yet moved into the realm of formal education. To avoid the “dangers of trivialization” or “keychain syndrome” of “making stuff” that will end up in landfill sites, Blikstein (2013) cautions educators to shy away from the kind of quick demonstration projects typically associated with makerspaces, and move toward learning that is more meaningful and contextualized. Our research examines ways to meaningfully integrate production pedagogies into the curriculum. This particular study revolves around a set of online “maker modules” developed by the research team. These modules focus on different maker technologies and

pedagogies and the impact these have on learning and engagement with real world issues. All of the modules focus on theory, research and practice and are linked to workplace experiences and the specific needs of the individuals completing them. The modules afforded the participants the flexibility to choose their level of completion based on their personal time commitments, location of study, and interests. Students were given the choice of completing the modules through an online synchronous, asynchronous, or hybrid structure, in which students could collaborate online or come into the lab to work with lab technicians and peers on “field activities”.

Our research questions for this study explored how a makerspace and maker pedagogies impact in-service educators’: i) learning in a graduate level course; ii) professional development in their teaching environments; and iii) willingness to adopt inquiry-based and student-centered approaches to teaching and learning.

### **Literature Review**

Current research makes use of the concepts of critical making as a way to utilize digital technologies and online interaction to achieve deep learning. Alongside a constructionist approach to education, critical making speculates that when learners are actively involved in the creation of tangible objects in the physical environment, learning is more effective. Students are able to rely on their knowledge and arrive at their own conclusions through investigation across multiple media avenues, resulting in the construction of novel understanding and relationships in the learning process (Kafai, 2006; Ratto, 2011). As opposed to traditional learning models (where teachers embed knowledge in the objects being delivered to and received by students), constructionist learning requires students to engage independently or collaboratively with raw materials to achieve the same learning objective. This project defines “raw materials” as both

tangible and virtual in nature. In conjunction with work done by Seymour Papert (1980), the “low floor, high ceiling” learning environment is relied upon, meaning that students may engage in digital making that requires minimal prior knowledge while offering opportunities for experimentation and concept development beyond the formal grade level of the student. Additionally, Resnick et al. (2009) built off of Papert’s work to include “wide walls” that encourage “many different types of projects so people with many different interests and learning styles can all become engaged” (p. 63). Many avenues for learning coding rely on this model, including technology tools like Scratch and digital circuit making tools like Arduino and Chibitronics; the maker modules enlist the use of these “low floor, high ceiling” computing and manufacturing tools to better engage students in the learning experience.

The primary goal of this study was to determine whether and how constructionist “production pedagogies” aid in the creation of students’ ‘performative’ capabilities in the realm of digital literacies. Additionally, analysis was done on whether or not these methodologies encourage civic engagement, service learning, and social justice. Critical making emphasizes the relationship between technologies and the social environment, shifting away from the culture of making for the sake of it (e.g., 3D printing keychains). The new framework concerns itself with liberatory and emancipatory potential of both the technology tools and their impact on education. This enables the shift away from the perceived dichotomy that exists between critical thinking and creative expression (Ratto, 2011).

Emerging technologies have been recognized as imperative for creating and encouraging a sustainable and resilient future, according to the SSHRC 2013 Technical Report, *Imagining Canada’s Future: Future Challenge Areas and Sub-questions*. Digital technology use has become omnipresent; this creates a challenge in education where new approaches are needed to meet the

demand of the growing young population. Mobile devices, social media, apps and games, 3D printing and robotics are becoming more widely accessible, so in order for these to be beneficial, educators need to better integrate and adapt to these technologies and acquire the skills required to be technologically experienced and relevant. The report discusses the need to lessen the digital divide in Canada and globally, which requires fostering digital literacy skills in both students and educators. More importantly, it is emphasized that today’s learners need to be able to not only adopt and produce but critique disruptive technologies as they become more widely used. Students must also fully comprehend the risks, opportunities and related ethical considerations with the use of these new resources. As indicated, new technologies that were only on the fringe of education a few years ago, such as 3D printing, are becoming more integrated into the homes and studios of the everyday citizen. They are no longer strictly for the business and manufacturing sectors. Personalized and local production are thriving, especially with the emergence and success of the DIY culture. An important consideration here is, what do we do with it? Our work with the maker modules attempts to assess these issues through the promotion and dissemination of theoretical frameworks and pedagogical practices currently found in digital literacies education.

## **Methodology**

### **Setting**

The participants in this study were enrolled in a graduate level course focuses on critical making, as digital pedagogy and applying “remix” as an analytic framework. Remixing may include (but is not limited to) prototyping, reverse-engineering, hardware hacking and circuit bending, design fiction, and policy or social analysis. The resulting "zombie media" (Hertz & Parikka, 2012) resurrects and repurposes digital objects and remix practices to uncover novel

connections and new meanings across sources. The course has three primary goals: 1) to critically explore the social issues inherent in critical making and production pedagogies; 2) to acquaint students with some of the affordances and constraints of new physical and ubiquitous digital technologies; and 3) to help students develop basic skills in designing, making, and/or evaluating educational uses of these new technologies.

This course uses a hybrid of synchronous (Adobe Connect) and asynchronous (Ning/Twitter) platforms. The course is broken down into 5 learning modules (see course website: <http://steam3d.weebly.com/>). The first class of each module takes place on Adobe Connect (<https://uoit.adobeconnect.com/a767860974/educ-5199g-201601-72138/>) and the second class takes place asynchronously over the next 10 days on the course Ning. In each module, Class A on Adobe Connect, focuses on the theory and research related to the module topic and Class B on the Ning, focuses on hands-on making (these are referred to as field activities). Students are expected to document their field activities using still images, video and/or written reflections, which are shared on the Ning. Students are encouraged to experiment with various modes of expression to get the most from the experience. The field activity artifacts constituted the students' final portfolios for the course and was formally evaluated. When time permitted, we also shared some of the reflections synchronously on Adobe Connect.

The online maker modules (<http://steam3d.weebly.com/>) are broken down into five topics: an introduction to the maker modules, electronics, wearables, 3D printing and programming (coding, gaming and robotics). The first module provides an overview to production/maker pedagogies and their growing importance/place in both formal and informal education settings. The second module (and the subsequent ones) is broken down into three sub-sections: scholarly readings with critical thinking/reflection questions; tutorials that are sub-



divided into introductory, intermediate and advanced walkthroughs (along with other supplementary learning and extension resources) and the assignments or activities associated with the tool. In the electronics module, the participant has the option to learn about or use one or all of the electronics tools provided -- Makey Makey, LittleBits, Arduino and Chibitronics. The third module primarily covers e-textiles, with a focus on LilyPad Arduino; the fourth module focuses on the 3D printing and its accompanying auto-CAD software TinkerCad; and finally, the fifth module covers a range of topics related to programming including coding, gaming and programmable robots, such as Sphero.

### **Participants**

There were 24 graduate students in the Critical Making course, which was offered from January - April, 2016. After the course was completed and grades were submitted, they were invited to participate in the research project. Eleven students agreed to participate and returned the consent forms. Of these eleven students, we have purposively selected two cases on which to base this paper (Palys, 2008). These two sample students were chosen in a non-random sampling for close case study examination and analysis. These two students produced comments, behaviour, and work that were exceptional and noteworthy. It is beyond the scope of the paper to describe all eleven cases in detail, given the vast amount of data that was collected. In this paper, we focus on the case stories of Edward and Harley. This course was Edward's last course of 10 courses in the M.Ed. program (course-only stream), and it was Harley's 4th course in the M.A. program (thesis stream). Edward lives in Canada's arctic as a senior policy analyst for the Government but when he began the program, he was employed by the Department of Education in the Assessment, Evaluation and Educator Development division. His interest in taking a course on critical making was based on Inuit culture that relies on “making” of all kinds. In his

initial blog post, Edward identifies himself as a “novice maker”, who wanted to create a clock for his son that would help him know whether to stay in bed or get up in the “land of the midnight sun”. Harley lives in the Greater Toronto Area. She was a recent graduate from a B.Ed. program and hopes to teach secondary school English, Social Science or Physical Education. In her initial blog, Harley comments, “I’m falling in love with maker culture, so I may have some remixing to do for my future classroom!” Both of these students were very active in both the online synchronous and asynchronous forums, collaborated with peers regularly and they both created websites to host their field activities and shared these with their professional learning community.

### **Data Collection & Analysis**

A mixed methods approach was used for this study -- primarily a qualitative case study methodology, which is appropriate for studying a ‘bounded system’ (that is, the thoughts and actions of students and teachers or the learning-community connection of a particular education setting) so as to understand it as it functions under natural conditions (Stake, 2000).

Supplemental mixed methods attitudinal data before, during and after participation in digital making, using surveys and questionnaires, was used to support and add context to the qualitative data. The surveys/questionnaires employed Likert scale and open-ended questions to establish baselines and to track changes in participant attitudes and experiences over time. Participants completed pre- and post- surveys at the beginning and end of the semester, to determine the types of digital making experiences they have engaged in (i.e. from authoring digital texts to creating tangible digital artifacts, and in what settings these experiences have taken place -- school, home, camp, etc.) as well as to gain insights into students’ attitudes about digital making. We also used student open-ended questionnaires at the end of each digital making activity.

Students were asked: a) what did you learn, and b) what did you feel? We also used Davies’ (2011) framework for understanding and assessing technology literacy, which focuses on three levels: awareness, praxis and phronesis (understanding why and in what context to use technology). The pre- and post-surveys and on-going questionnaires helped determine shifts in experiences and attitudes towards digital making and allow for comparisons across cases and research settings and for triangulation, using this data along with observations, field notes, audio and video recorded classroom activities, students’ work products and digital products, interviews with students and digital artifacts shared through the project website.

Analysis of the data required several different layers of coding and interpretation. In the first stage the bulk of the data was coded for various themes that relate to our research questions. We coded the interview transcripts following traditional coding procedures (Strauss & Corbin, 1990) and compared themes across the different research settings in order to identify recurring and overlapping thematic and structural patterns (Black, 2007).

### **Findings**

As Edward and Harley progressed through the maker modules and engaged in reflective learning through pedagogical documentation, in both cases, the creation of a learning website and frequent discussion posts to the classroom social media site, Ning) they also progressed quite evidently through Davies’ (2011) theoretical framework for evaluating educational technology integration. This framework includes three distinct phases: the awareness stage where teachers become aware of the various technology available to be integrated into their pedagogical practice. Next, the praxis stage, which is where teachers begin to use and become familiar with the technology, and they are generally excited about the technology tools and their potential, but do not necessarily have the knowledge or competence yet to know where, why and how to

integrate the tool most meaningfully into their practice. Finally there is the phronesis stage where both competence in the tool and wisdom of best practice with it are achieved. Both cases are discussed in more detail below.

### **Edward**

Edward, who attended the course from his home in Nunavut, Canada, stood out as a noteworthy case study in this group of students, not only due to his remote geographical location, but also his unique experience learning and applying the tools. At the beginning of the course, due to limited access to the various makerspace tools, Edward had no choice but to learn how the tools worked, what they could do and how they could be used in the classroom, online. As a result, he went through a more “theoretical” learning process. Another unique factor that made Edward stand out was the community in which he would be using the tools -- Inuit youth in the north who have been left-behind by a curriculum ill-suited to their needs and lived experiences. Both these factors may have influenced his relatively quick progression through Davies’ (2011) framework and resulting adoption of the tools and their surrounding pedagogy.

In the Awareness stage, where teachers’ talk about the technology is prevalent as they become familiar with the tool(s), Edward states, “Seems like an important factor is how the technology [makerspace tools] allows for intersections among the digital, real, disciplinary fields etc... Connecting it all together”. This statement was taken from an Adobe Connect session in the early weeks of the course where Edward was just beginning to explore the various technologies available now for classrooms. Throughout his chats and early discussion posts, it is clear the tools and their potential sparked an interest for him, but his reliance on discussion about the tools and watching others use the tools online (i.e., tutorials) may have provided him a different perspective and understanding. This perhaps afforded Edward an extended opportunity

to reflect on the tools and their affordances and constraints, before becoming distracted or caught up learning the various basic features. As Davies (2011) outlines in his paper, using tech tools’ features incorrectly, or not for their original purpose, is a key indicator of the praxis stage.

As Edward then began progressing through the maker modules, he started to learn more about some of the tools, including MaKey MaKey, e-textiles, TinkerCad and CodeCombat. At this point, Edward has moved into Davies’ (2011) praxis stage, where familiarity and excitement is prevalent, but mastery of the tool and meaningful integration is not yet solidified. Specifically, in his Module 2 field activity, Edward focuses on MaKey MaKey. In his response to the tool, his excitement -- yet, still not expert understanding -- is apparent: “If I were a classroom teacher at this time, I would definitely employ Makey Makey in order to help students learn about circuits, electricity and design. The wide walls inherent in Makey Makey’s design offer many opportunities for open-ended exploration and application to diverse problems. Finding the balance between pre-planning and structured activities and open-ended discovery would be a challenge for me in using this tool. My temptations to let the learners’ imaginations run wild would be high.” Here, Edward’s limited familiarity with MaKey MaKey would be a constraint in terms of fluid classroom integration, which may impact the desired outcome of student engagement and success. His limited experience with the tool would affect the framework and scaffolding of the learning process. It is clear from Smith, Iversen and Hjorth’s (2015) work on design thinking for digital fabrication in education, that having a scaffolded, iterative creation framework, such as the design process to work within, yields the best results in terms of student engagement and the purposeful creation of tangible and digital artifacts.

Toward the end of the course, Edward appeared to have reached what Davies (2011) considers the phronesis stage in his learning and meaningful integration of the technologies. This

was most apparent in his provocation project created with the online digital tool, Adobe Voice (<https://voice.adobe.com/a/j5w68/>). Through this multimodal presentation software, Edward outlines how to incorporate critical making as an authentic learning assessment for his specific demographic of learners -- Inuit youth in Nunavut. The “practical competence and practical wisdom” (p. 45) that Davies (2011) refers to in the phronesis stage is most apparent when, in the video, Edward fluidly integrates maker pedagogy (making as learning and the design process) with the new digital maker tools he had become familiar with in the course. In his presentation, Edward discusses how the traditional standardized exam in Nunavut -- the Alberta Diploma Exam -- is used as an assessment tool and is a requirement in order to receive grade 12 science credit. What Edward instead proposes is a critical making activity framed in authentic assessment (McTighe, 1997) and grounded in Aboriginal and culturally responsive pedagogy (Jester and Fickle, 2013), problem based learning (Gallagher & Gallagher, 2013), critical making (Ratto, 2011) and pedagogy (Freire, 1970). Instead of sitting a non-context-specific exam based on memorization and recall, Edward proposes a final digital fabrication based assessment of student learning in science (grounded in a local-setting-based curriculum and therefore embracing student knowledge), which would potentially help close the education participation gap for Aboriginal learners. Edward outlines that the assessment would be composed of the following five main components:

- 1.) Students identify a societal issue that affects their community.
- 2.) Students research and write persuasively about the problem.
- 3.) Students plan and develop a design to address the problem.
- 4.) Students make a prototype.
- 5.) Students present their prototype to real world audiences.

Essentially, the assessment is based in the science curriculum and asks the students to demonstrate mastery instead of rehashing facts on a page. In this way, students use their learning in science to show they can solve a real world problem. The assessment would take place over a predetermined period of time, so the students would have the opportunity to refine their work, get descriptive feedback and collaborate with one another -- all key elements in a maker-based classroom. Furthermore, Edward outlines that the classroom environment would be set up like a design studio or makerspace, re-connecting elements, tools, subjects and skills that otherwise end up in their own silos. That Edward was able to not only learn the maker tools, but use them so meaningfully -- grounded in strong pedagogical frameworks -- indicates that he has reached the final phase of Davies' (2011) technology integration. The overt need within this unique setting for a dramatically different approach to education and assessment may have accelerated Edward's uptake or adoption of the tools and the associated pedagogies. Similarly, his unique process of learning the tools first theoretically (allowing him the time and space to “sit” with them and learn their features and affordances more broadly) may have also made the act of learning the tools in the practical setting, once he got to this, a more fluid process. From Edward's final provocation project, it is clear, that he managed to move from novice to expert in terms of meaningful technology integration in the classroom.

### **Harley**

Based on time spent in the instructor's Maker Lab, Harley entered the course with an alternative perspective regarding the makerspace movement when compared to most of her peers. She entered as one of only 12 students strongly identifying as a maker, having had some tangible experience using the tools that would be addressed in the course, placing her at an advanced level in Davies awareness stage. In a quote from her first blog post on her course

blogging webpage, Harley recognizes that as a student she was often “more successful when given the opportunity to try something for myself or get “down and dirty” with materials.” This statement, along with the documentation of her process during each module, exemplifies a willingness to engage and “tinker” with the tools becoming available throughout the course, whether the final product was successful or not. Harley addresses a peer’s concerns early in the course stating, “That’s why we try to emphasize the process rather than the product of the making,” emphasizing the importance of the journey and learning along the way, not the result. There is a recognition and awareness on her part of the importance of a makerspace-learning environment, putting her past the initial stage of awareness and into the developing praxis phase early on in the course.

As she moved through the course, she developed through Davies praxis stage, specifically through the attempts at solving problems prescribed through course activities. Rather than simply tinkering with the tools, the field activities moved towards useful applications of the technology or apps. In Module 4, Harley developed a “how-to” guide for the use of a 3D pancake printer for potential use in a classroom or the instructor’s Maker Lab. The project shifted towards making with a purpose rather than making for the sake of playing with a new tool. It was in this model, that the movement towards the stage of phronesis began to occur.

Harley began to reflect Davies (2011) position regarding the efficiency and effectiveness of guided instruction in this type of learning environment rather than complete exploratory freedom. She discusses the evolution that would be required in the classroom with “the teacher’s role will be to ensure that they remain on track and are satisfying the needs of the assignment, rather than walking them from point A to point B.” This mindset works in tandem with the pillars of the evolving maker paradigm for education, where the teacher is no longer the “sage on



the stage” and is able to grow and learn with technologies alongside the student population. Prior to reaching Davies (2011) stage of phronesis he mentions that, “The user must understand the learning task and recognize the ways the technology will facilitate attainment of the learning goal.” Earlier in the course, during module 2, it was clear that Harley was struggling to achieve praxis with regards to the work with Chibitronics technology. She had some learning experience facilitated by a colleague with regards to the tool, as well as did personal e-learning through online videos and webinars. However, when it came to putting the theory to practice, the final project was left incomplete. For part of her Module 2 blog Harley mentions, “So, after multiple attempts with that I couldn't seem to figure out what was going on. After the couple hours I had been playing I got incredibly frustrated and needed to walk away and take a break.” This resulted in the project remaining incomplete and the bulk of the assignment being a reflection on the tool and Harley’s hopes for its use in the future. When shifting to the final modules, Harley expressed several times in her blog that the technology tools should be used to emphasize learning goals and projects, not replace them, so this shifting mindset speaks to her movement into the phronesis stage. During Module 5, where the focus was on coding, Harley was able to recognize the deficits of the programs being addressed emphasizing her growing ability to know “why the technology is being used or not being used” which Davies (2011) notes as a critical aspect to phronesis.

### **Implications**

There was an incredible, almost exponential amount of learning that occurred during the critical making graduate course. Some students came in with limited or no experience, but even the students who were more proficient with technology in general, stretched themselves. From the beginning, the engagement levels were high. Most of the students ventured outside their

comfort levels and persevered through a multitude of challenges. Perseverance, grit and resiliency are common skills that often developed or strengthened in a makerspace learning environment. Particularly noteworthy is that most makerspace studies have focused on children, adolescents and young adults who are believed to have more brain plasticity than adults. Perhaps, however, it is the adult brain’s ability to plan (frontal lobe/executive functioning development) and the potential for greater patience that allowed these adults to stick with their learning project until its completion.

Another key finding was that the students generally involved one another in the learning process, and this is an important factor when learning by doing (Vygotsky, 1978). As Vygotsky indicates, learning is a social process and being able to draw on others’ lived experiences and knowledge accelerates the learning process. As the students progressed they became more comfortable engaging with the “hack this assignment” option. They started out wanting to be told what to make or do but they became more comfortable with venturing off the road map. In this sense, they willingly began to adopt the inquiry process, most likely due to the safe learning environment we had built in the classroom, and also their growing comfort with the tools and the reframing of failure -- failure being seen as not something negative, but a necessary element on the path to mastery. By the end of the course, it was clear to see that the maker modules had a tremendous impact on professional development -- understanding of where and how to meaningfully integrate the tools and maker pedagogy, as many are going to start makerspaces in their schools and some have already started incorporating makerspace centres in their classes.

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