Literature Review: Making and Tinkering as an Educational Tool

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Abstract

This literature review provides a background and general survey of the literature to date concerning making and tinkering. In particular, this review focuses on the literature, or sometimes the lack thereof, as it pertains to the applications of making and tinkering strategies to undergraduate education in the field of Electrical Engineering. This document is meant to provide a basis for our research and provides context for the educational exercises which will subsequently be developed.

1 Introduction

As acknowledged by Yoder et al. 1998 [1], the interests of undergraduate engineering students tend to shift with time, and the technology available to undergraduates has advanced dramatically since the turn of the millennium. Many researchers suggest that it is time to facilitate changes in the educational establishment in order to cater to and take advantage of these changes. Consequently, making and tinkering (M&T) as learning practices have been gaining attention and momentum in recent years and may be the solution we seek. The Maker Movement is sweeping the nation, and many are embracing its potential to revolutionize our educational system [2] [3]. Though it has arguably revolutionized informal learning environments, large scale integration into formal education has not been implemented. A blending of informal and formal learning environments have been increasing though, with more after school makers club becoming available [4]. The driving force of the movement is that the employment of the M&T strategies has the potential to provide an effective avenue to improving current educational strategies. Vossoughi et al. 2013 [5] acknowledged these strategies as a refreshing and effective approach to promote entrepreneurship, STEM recruitment, workforce development, and inquiry-based education. It is important to note that most research that has been conducted in relation to M&T to date concerns the observation of K-12 students up until recently, where a big boon can be seen in universities inclusions of makerspaces. Little existing research prior to a few years ago pertains to the implementation of M&T learning strategies in relation to undergraduate engineering courses, although there are some [6].

1.1 History

Though the Maker Movement is relatively new, it draws on many already established educational strategies. Papert sets forth the idea of constructionism, which he describes as favoring "forms of knowledge based on working with concrete materials rather than abstract propositions" (Papert et al. 1991 [7]). This idea of constructionism is further explained by Wagh et al. [8], saying "constructionism emphasizes designing objects for learning that embody structural ideas of a content domain in ways that are intuitively accessible and engaging to learners.", furthering the notion of using relatable objects as key teaching tools. Jack Mezirow et al. [9] describe transformative learning explaining that, "We learn differently when we are learning to perform than when we are learning to understand what is being communicated to us". Pre-existing notions of active learning, which Tom Briggs et al. [10] may help to describe, often align with ideas related to present day M&T. M&T helps to facilitate learning by closing the gap between learning and development, described by Vygotsky [11]. It also subscribes to Vygotsky's suggestions on the internalization of higher psychological functions, arguing that purpose is key to understanding.

1.2 Defining Making and Tinkering

Making and tinkering are loosely defined terms. As Papert et al. [7] describe in their writings on constructionism, providing a strict definition and process in relation to these terms and their related strategies may contradict the efforts to employ them in a learning environment. These strategies are meant to provide an expressive and interactive learning environment to aid with the internalization of information as a means to an end. In order to preserve the nature and authenticity of these strategies, a certain degree of freedom must be maintained in association with these strategies. To remain genuine, students must be able to properly express their own creative adaptations of a problem and its respective solution. Therefore, strictly defining M&T and their related strategies may limit creativity and expression, thereby impeding the desired educational effect.

However, it could be beneficial to give some structure to strategies associated with M&T so they might be implemented in a formal university environment. Furthermore, these structures must be consistent if they are to be accepted by and integrated with the current educational establishment. As stated in Sheridan et al. 2014 [12], "it may be easier to design, teach and study more constrained making activities." As such, here is a culminating description of M&T as it pertains to our field of study using a collective of existing studies as a basis.

M&T may be described as a type of hands-on and self-directed learning. M&T describes a state of mind achieved by pursuing a form of active learning in which knowledge is often sought as a means to accomplish a particular task in which one is personally invested. As can be gleaned by the denotation of the words, these tasks are often rooted in physically making, or tinkering with, products. In simpler terms, M&T is a new approach that draws from many older educational strategies.

It can be best to think of M&T as an umbrella under which many strategies can be found. Important aspects of making and tinkering typically include community support, self-expression, personal investment, iterative design processes, fluid expert/novice roles, inquiry-based learning, project-based learning, problem-based learning, learner-driven inquiry, interdisciplinary, and invested facilitators in place of instructors, among other aspects. Within M&T, some refer to the individual terms "making" and "tinkering" as seemingly independent emerging strategies. Blikstein et al. [6] describes tinkering as a type of making. Generally, it seems that there is too much overlap between the two to separate them in either of these fashions. It can be posited that the idea of tinkering tends to favor experimenting, specifically with the use of tools, whereas making favors creative expression. However, both of these aspects come to mind when thinking of either word. So we refer to them as a unit, M&T, as does DiGiacomo et al. [13].

2 Findings

2.1 Current Trends

The Maker Movement has been gaining ground largely in the form of informal education primarily for children, using adults as facilitators, though learning roles are not so traditional when speaking about M&T. To date, it appears that making and tinkering have made themselves most prominent in museum exhibits and informal community makerspaces. One particular example of a community makerspace is Sector67 Makerspace in Madison, Wisconsin described in Sheridan et al. 2014 [12]. Similar to other makerspaces around the country, they encourage both youth and adults to engage in M&T activities in order to grow and learn informally as a means to accomplish a goal. They facilitate makers who participate as hobbyists, elementary learners, entrepreneurs, and handymen. People come in to cut pipe for plumbing repairs at home. People come in to create art, such as bike chain sculptures. Some patrons use the facilities to create product for small businesses. Projects can range from small solitary undertakings to a makerspace wide events, such as Sector67's annual iron pour which hundreds attend. Museum exhibits also may contain makerspaces. For example, the Children's Museum of Pittsburgh contains MAKESHOP, which is a makerspace. MAKESHOP provide some basic supplies and a facilitator to help with what we might think of as arts and crafts, only with a special twist. They provide patrons with interactive activities designed to facilitate inquiry based self-learning, often focusing on basic properties of circuitry, programming, or other STEM facets. While these two makerspaces serve as examples of what may be, they are not alone in their contributions or accomplishments. Other well documented makerspaces or related undertakings include: the Exploratorium (San Francisco, CA), the Mt. Elliott Makerspace (Detroit, MI) , the Transformative Learning Technologies Lab (TLTL) projects at Stanford University, and Maker Media.

Adaptation of these maker trends into the public school system are mostly in the form of after-school making activities. An after-school program allows for an easier mesh of formal and informal learning environments, creating a setting that is a mix between a directed classroom and an open workshop [4] . Ryoo et al. details an after-school program created for youths to develop "learning dispositions, creative problem solving, and deeper understanding of STEM concepts and practices." [4] . The blend of environments creates a unique setting that fosters learning by exploration to children who have typically learned only through traditional methods, inspiring them to take "creative and intellectual risks" to find new solutions. These programs allow exploration-based learning while also being semi-directed, and are great tests for the validity of this type of education within an academic setting.

Despite the fact that many schools are still uncertain about these methods, some schools, both K-12 and universities are testing out M&T centric portions of curriculum [6, 14]. Barrett et al. specifically notes 35 different universities that have adopted a form of makerspace into their facilities, ranging from rudimentary setups to more involved and detailed [14]. Peppler et al. [15] posits that this surge of interest towards M&T format may be because project-based learning, another innovative, hands-on teaching method, has done well, especially with STEM topics. These makerspaces provide places for university students to come in and explore hands-on, which is both good and bad. Since it relies on the students to want to come in based solely upon their own motivation, many will miss out because a class they are taking isn't putting them in that position.

2.2 Existing Research

While there is substantial research documenting making and tinkering in informal environments such as public makerspaces, there is limited documentation concerning the structuring and application on a large scale of M&T to a formal undergraduate program in engineering. As previously stated, many universities have began to provide makerspaces, yet the complete integration of M&T into a course curriculum has rarely occurred. Ortiz et al. shares one of the few seen examples of M&T centric curriculum being implemented in undergraduate classes, discussing three separate classes at different universities using M&T tactics within their curricula [16]. Integration of tinkering into mainstream pedagogies hinges on the success of trial classes implementing it, such as these.

Briggs [10] does provide insight into how active learning may benefit undergraduate CS (Computer Science) courses, yet it is theoretical rather than a concrete example of its implementation. Vossoughi et al. [17] provide a well-rounded and in depth literature review of M&T in general. As discussed earlier, Sheridan et al. [12] provide a comparative review of three informal makerspaces. Though it is dated, Yoder et al. [1] expressed a need to restructure courses involving Digital Signal Processing (DSP) and stressed the importance of this topic to undergraduate engineering courses specifically in electrical engineering programs but also in other disciplines. Bevan et al. [18] have provided a categorization of key elements to tinkering based on conducted studies.

Various researchers have conducted case studies as precursors to publishing, and others have published based on experience and informal findings. Bevan et al. [18] have provided a categorization of key elements to tinkering based on conducted studies which they suggest as a framework for further research. They discuss four learning dimensions of tinkering including engagement, initiative and intentionality, social scaffolding, and development of understanding. They conclude that a properly orchestrated tinkering facilitates development via these dimensions. Blikstein [6] concludes that there are five important design principles to be considered when incorporating tinkering into coursework. Among these are the significant complexity, emotional involvement, interdisciplinary, contextualized learning, and the intellectualization and re-evaluation of existing understandings. Resnick and Rosenbaum [19] have suggested certain design criteria based on their experiences and m to be a recurring source to many publishers. Vossoughi et al. [17] concluded that making can be implemented in a way that positions and supports youth to actively participate in science and that making supports both learning and development. They also discovered that making helps to create a supportive learning community.

3 Evaluation of Literature

3.1 Tensions and Cautions

As with any new strategies, there are still many uncertainties. We identify possible areas of conflict between M&T strategies and the current educational establishment at the undergraduate level. First, schools have set curricula that typically subscribe to accreditation standards. That is to say that they must be careful not to upset the current establishment and its governing politics, or these new ideas will be cast aside. There are other aspects of M&T that will be hard to facilitate, such as a proper sense of "community", often described as necessary to maker programs. Professors alone will not be able to cater to students in large class sizes and maintaining a sufficient number of TA's with the proper experience is not likely to be feasible. Students will have to be encouraged to create their own collaborative communities, which in turn may upset current norms, being that students are expected to perform a majority of tasks individually and generate original works. So, teamwork and collaboration can only be supported to a certain point, less some students start to graduate without ever gaining proper experience. Moreover, allowing excessive freedoms can complicate grading and documenting associated with coursework and may make it hard to fairly evaluate different students. Many researchers have also given their own cautions. Vossoughi et al. [17] cautioned against the "fetishization of tools" within new strategies of M&T. Because having access to new and powerful tools is a large part of M&T, Vossoughi worries that people will attempt to implement M&T without other critical aspect such as community support, inquiry-based learning, and other mindsets. In which case it might be written off as another expensive and failed strategy. Vossoughi et al. [17] also warn against short research periods, likely in relation to all the "museum" research that takes place, as well as minimizing the role of teacher and allowing "teaching" to become taboo in lieu of "facilitating". Instead, Vossoughi suggests that we integrate and blend M&T strategies with current educational approaches.

3.2 Gaps in Literature

Several areas of study related to M&T as an educational tool are lacking in research. There are no apparent records detailing a comparison between typical educative practices and a practice that incorporates strong aspects of M&T in a university environment. There has also been very little discourse involving M&T in general in a university environment, outside of recent universities providing makerspaces. However, Blikstein [6] does touch on the relationship between M&T methods and the thought processes related to college level engineering courses. No apparent studies have been conducted in regards to the fusion of formal techniques and M&T. Furthermore, no formal discourse has taken place regarding the degree to which M&T can be effectively implemented at a college level.

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