How Making and Makerspaces Promote Healthy Mindsets for Learning

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ABSTRACT

When we opened our first campus makerspace at Elon University in 2015, our mission was not to provide access to 3D printers and sewing machines. We wanted to create an interdisciplinary space that was grounded in sound pedagogical research and practice, with the goal of helping students repair their damaged relationship with learning.

Research indicates standardized testing in K-12 negatively impairs college students' perceptions of what learning is and how it works [1]. Stevens and Miretzky's [2] work indicates faculty already observe these negative effects on college students' attitudes toward learning, with students struggling to master challenging work, failing to recognize the link between effort and success, and lacking a willingness to struggle with complicated ideas and theories. Maker education and makerspaces represent one approach to confront and combat these negative effects of standardized testing.

MAKING AT ELON

A. Background

We opened the Maker Hub, Elon University's first makerspace, in August 2015. It was one of the first college makerspaces to be housed in a residence hall. Despite its location, the Maker Hub is open to all students, faculty, and staff.

Our space is under Teaching and Learning Technologies within Instructional & Campus Technologies, and is not affiliated with a specific academic department, school or discipline. Maintaining a "discipline agnostic" philosophy has allowed us to focus on designing maker activities and initiatives that have broad, interdisciplinary appeal.

The space was overseen by two professional staff members in Teaching and Learning Technologies, and operated by a team of eleven paid student staff. The student staff included two team leads: Team Lead for Operations, and Team Lead for Training & Development. These students handled the hiring, discipline and firing of student staff, coordinated with faculty and professional staff to schedule orientations and training, and assigned other students to lead those sessions.

The Maker Hub opened with five core modules: 3D design and printing, e-textiles, mobile app development, microcomputing, and electronics. The intention with these modules was to provide basic-to-moderate level equipment for students to develop on before graduating out to more advanced spaces or academic programs on campus. For example, a student who mastered using our sewing machines could transition over to the Costume Shop, which is in the Theatre Department. This concept led to the name "Maker Hub" because we view the space as a metaphorical hub for maker activity across campus.

B. Current Progress

We opened our second campus makerspace in Fall 2017. Keeping with the Maker Hub naming convention, our current space was updated to Maker Hub - Colonnades to reflect its location in a residential neighborhood. The new space is named Maker Hub - Downtown, and is located in downtown Elon. The downtown space is ap-

proximately twice as large as the residence hall space.

We've also refocused the core modules. Maker Hub - Colonnades supports e-textiles, 3D design and printing, and crafts. Maker Hub - Downtown supports 3D design and printing; microcomputing; e-textiles; electronics; basic wood-working; and laser cutting. Both spaces will be overseen by a full-time staff member and sixteen paid student staff.

PEDAGOGICAL APPROACHES TO MAKING

A. Constructionism

Constructionism is often cited as an underlying principle of maker education. Constructionism is a theory of learning based on Jean Piaget's philosophy of constructivism, and extends the process of meaning-making to constructing tangible, shareable objects [3]. It is an inquiry-based form of learning.

Though constructionism is popular in academic literature on making, we don't emphasize it in our work with the Maker Hub due to several weaknesses in the research. Namely:

1. The research does not currently address legitimate criticisms of constructivism, including the lack of empirical evidence supporting its efficacy, especially for novice learners [4]. This is concerning given its position as a foundation of constructionism.
2. Many citations of constructionism are recitations of the same core texts from the theory's creator, Seymour Papert, rather than supporting literature or evidence.
3. Explanations of constructionism in research are often framed in a way that unfairly positions or mischaracterizes other methods of learning or instruction (e.g. "learner focused" versus "teacher focused"). Other forms of instruction are frequently framed solely as lecture or rote memorization of facts, which fails to represent the diversity of available instructional and learning strategies.
4. Along these lines, many explanations of constructionism actively diminish the role of the instructor under the rationale of promoting student agency, while overlooking the instructor's role in creating experiences that promote this agency, and in providing appropriate challenge and feedback for growth.
5. The learning-by-doing/making/exploring approach goes against established research in how novices best learn [4], and leaves out students with learning impairments [5]. For example: Some proponents of constructionism dismiss the value of providing examples in favor of a discovery approach, when the worked-example effect is proven to be an effective cognitive strategy for novice learners [6]. Furthermore, Direct Instruction (DI) is often positioned in research as an inferior approach to constructionism, despite substantial empirical evidence of its effectiveness for students with learning impairments [5].

I do acknowledge that observations of a space that is characterized as a constructionist learning environment will likely show students learning. The question is not *if* students are learning, as they usually are. The question is whether constructionism is the *most effective* approach for those students given where they are in the learning process. Furthermore, the students who succeed in constructionist learning environments likely A) already have a baseline combination of skills and knowledge that make an inquiry-based approach more effective, or B) are receiving supplemental and complementary instructional approaches (such as DI and instructional scaffolding) that are not explicitly identified in the research.

B. Design Thinking in the Maker Hub

Design thinking (DT) refers to a collection of strategies that designers use to solve problems, particularly problems that require creativity, or whose solutions are extremely difficult to define [7]. The focus is on developing solutions that both work well and feel good to a specific person or group.

Elon University has devoted considerable resources to furthering DT as a teaching and learning strategy across campus, culminating in the establishment of a Design Thinking Center (with two more planned for the future). Our

new Maker Hub location is located directly adjacent to the current center. While we highlight some DT concepts and elements in the Maker Hub, we rarely train students to use a full process. The primary area we've found elements of DT to be useful is within our Elon Kickbox grant.

Elon Kickbox is a grant program offered through the Maker Hub. Students apply with an idea they'd like to turn into a reality, which could include a physical or digital product, or something more abstract like an organizational process. Applicants must find a faculty sponsor who is willing to endorse the value of the student pursuing that project. Submissions are reviewed by a panel of faculty, Maker Hub student staff, and professional staff in fall, and recipients have all of spring semester to work on their project before presenting their work at a regional Maker Faire, as well as an undergraduate student research event.

An Elon Kickbox contains two primary elements: 1) A $300 Visa gift card that can be used to purchase anything reasonable for the project, and 2) An iterative design process that helps the Elon Kickbox recipient take their idea and make it actionable. Professional staff provide training on this process during the kickoff meeting for the program. This design process has proven to be so valuable that nearly a quarter of Elon Kickbox recipients have returned the full $300 balance of their grant at the end of spring semester. These students identified the design process as the most valuable part of the box, and reported being able to use this process to make meaningful progress on their idea.

C. Design Thinking and Maker Education

Like the maker movement, DT is emerging as a trend within business and education. Both are also new names for old concepts. Because making and DT are emerging rather than established elements of the academic lexicon, confusion still exists about the full context of what making or design thinking truly mean. As a result, I often observe confusion and blending when defining both making and DT, with the implication that the two are fundamentally the same. This is not the case.

I do not consider the practice of making to be the same as the processes of DT. There are similarities between the two, specifically the elements of rapidly prototyping and testing a design, as well as iterating on a design across multiple revisions. However, enough differences exist between making and DT approaches to confirm their distinct identities (Table 1).

Table 1: Differences between Making and Design Thinking

Making	Design Thinking
A theory of learning through creating and sharing	A collection of practices for solving problems
Learners construct physical or digital products that can be shared with others	Learners construct physical or digital objects, ideas, or processes for others
Core focus is on developing a maker mindset to improve learning	Core focus is on defining problems and developing solutions that are empathetic

In short: making is primarily focused on learning, while DT is primarily focused on solving a problem. DT is an effective strategy for working on a maker project, especially if that product is for an outside audience, but the two are distinct approaches that should be clearly defined when communicating with educators and learners who are new to either concept.

D. The Danger of One-Size-Fits-all

While plenty of enthusiasm exists around the potential of making to affect change in education, it would be wise to temper that enthusiasm in a way that honors existing research in teaching and learning. Many supporters of maker education appear to rail against a "one-size-fits-all" approach to traditional education, yet in the same breath will promote maker education as a one-size-fits-all solution.

Consider the process of learning to play piano. Constructivist supporters might point to student practice as an example of learning by doing (and they'd be right). But the foundational cognitive work of learning to play requires substantial DI from an instructor to introduce concepts like the musical scale, hand placement, and reading sheet music (work that does require the development of so-called "lower order thinking skills"). The students also practice established songs rather than creating their own; songs that progressively intensify in difficulty, while combining new and estab-

lished concepts. These experiences contain scaffolded instructional support that gradually diminishes over time as student competency develops. At the same time, the students have the agency to work ahead, or utilize external resources to further their learning.

In a maker learning environment, a constructionist approach will not be as effective for novice learners, or students with learning impairments, without substantial complementary support from DI and worked examples. The instructor must also scaffold learning experiences as the students develop skills and knowledge, which will help develop their confidence and agency. The instructor can leverage these strategies to transition their students into a constructionist-based environment.

This transition can be smooth if managed well by the instructor, especially since these beginning strategies diminish in effectiveness as the students improve and begin to adopt a more constructionist approach to their learning.

DI, a subset of direct instruction also referred to as "explicit instruction", is a collection of instructional practices that can include discussions, lab work, tutorials, workshops, observations, or active learning strategies [8]. These practices become less necessary in a makerspace environment over time as the students develop skills, confidence, and autonomy.

Worked examples (defined as step-by-step demonstrations of how to solve a problem) are more effective than problem solving for novice learners [6]. However, these examples diminish in effectiveness, and are disruptive to learning in some instances, once learners reach certain levels of competence (referred to as the expertise reversal effect) [9].

Instructional scaffolding (a system of supporting students when they're first learning a concept or skill), with appropriately designed high levels of guidance, is proven to be more effective for learning than the lower levels of guidance endorsed by constructivist proponents [10]. However, the purpose of instructional scaffolding is to gradually remove this guidance and support as students develop. It can function as a segue to constructionism.

Given these complementary relationships, it would be wise to avoid an "us versus them" mentality within constructionism, and begin embracing the value of teaching and learning strategies that have historically been presented in direct opposition to the theory. There is clear evidence to support the use of instructional scaffolding, DI, and worked examples to transition novice and impaired learners into a constructionist environment. A complementary set of instructional strategies alongside active involvement from the student and the instructor are required for effective and lasting learning to occur in any learning environment. Learning is remarkably contextual, and no one instructional or learning strategy will work best in every situation. The best solution is often a combination of strategies, even when those strategies appear to be philosophically at odds.

WHY MAKING MATTERS

A. Standardized Testing, Perfectionism, and Unhealthy Learning Habits

Standardized tests exert enormous weight in K-12 education. A student's test scores can determine state and federal funding for their school and district, their teachers' salary, and which level classes they are placed in the following year (consequently, these class placements also influence which peers and peer groups the student can regularly interact with).

Given the stakes, students are routinely exposed to direct and indirect pressure from multiple sources throughout the academic year [11]. Though some adversity is good for children because it helps them develop resiliency [12], too much can be detrimental. From the time a student in the United States enters prekindergarten to the time they graduate, they will have taken an average of 112 standardized tests [13]. This is a tremendous amount of pressure to place students under. This pressure builds over time, reinforcing specific mindsets that can distort a student's conception of what learning is, how it works, and their ability to function as a healthy learner. Worse, this pressure can change how a student views and assesses their worth as a learner, and as a person, manifesting in behaviors and mindsets

classified as perfectionism. These harmful mindsets can include:

- Disregarding the process of learning, and focusing exclusively on the outcome of a learning activity
- Setting unrealistic or unattainable goals for performance on a task, and viewing re-alignment of those goals as an admission of failure
- Defining success as a lack of failure
- Considering even minor imperfections as an indication of failure

There is a distinct difference between a desire to be a high achiever and perfectionism. The perfectionist will never view anything less than perfection as acceptable, which has a maladaptive effect on their sense of self. Perfectionists also develop an aversion to being challenged in academic contexts [14]. This aversion is driven primarily by fear, including any combination of the following:

- A fear of failing a task
- A fear of appearing to be a failure
- A fear of not embodying a label they've been given by someone important to them (e.g. someone who's told them they're "smart" or "talented")
- A fear of disappointing people they care about (family, friends, instructors)
- A fear of working harder (a sign that they're not good enough to be immediately successful)

The manifestation of these behaviors in higher education seems to be mischaracterized as laziness, entitlement, or apathy. While some students may be lazy, entitled, or apathetic (a possibility in any generation), I propose assuming the best of our students rather than the worst.

If we acknowledge the pressure our students have endured throughout their K-12 education, and the mental and emotional turmoil that perfectionism inflicts on an individual, we can begin to re-contextualize these behaviors in our students. Is a student procrastinating because they're lazy, or are they struggling to start because they're afraid of doing something wrong? Are they entitled because of their laser-like focus on earning an A, or have they been taught (explicitly or implicitly) that no other grade will mean they're good enough? Are they apathetic, or do they care *too* much? It's decidedly easier (and socially more acceptable) to say, "I don't care" than it is to say, "I'm anxious and struggling" [11].

The mental and emotional stress of perfectionism and perfectionistic tendencies have a clear, damaging influence on our students and their relationship with learning. Worse, these impacts don't just sustain an unhealthy relationship with learning–they also leave our students more vulnerable to depression, anxiety, suicide, and other mental disorders [15]. These circumstances provide an opportunity to position and establish maker education as a high impact educational practice that extends beyond the realm of teaching and learning. While making can improve our students' learning in the right circumstances, it also holds the potential to positively affect their mental health and wellbeing.

B. Core Philosophy of the Maker Hub

The foundational goal of the Maker Hub is to help Elon University students repair and develop their relationship with learning. Though I assign no blame to our colleagues in K-12, I also cannot overlook the impact the culture of standardized testing has on students' perceptions of learning [1]. Stevens and Miretzky's [2] work indicates faculty observe these negative effects on college students' attitudes toward learning, with students struggling to master challenging work, failing to recognize the link between effort and success, and lacking a willingness to struggle with complicated ideas and theories. Approximately half of the study participants indicated their students' ability to demonstrate those skills had declined over the past decade. This timeframe aligns with the assessment and accountability movement in K-12 education, reinvigorated in the United States by the No Child Left Behind Act of 2001.

My conclusion is that standardized testing has damaged students' relationship with learning in the following ways:

- Reinforcing the concept that learning is an outcome instead of an ongoing process

- Allocating disproportionate weight to a test grade as an accurate measurement of academic (and personal) worth
- Tangentially endorsing habits that lead to and sustain perfectionism, including defining success as a lack of failure, and reinforcing the false notion that a student must be exemplary in every academic subject

The goal of the Maker Hub is to repair and develop our students' relationship with learning by promoting behaviors, mindsets, and practices that counteract the effects of standardized testing. We do this by promoting our version of a maker mindset. Though this concept has existed in several forms [16], we define the Maker Hub's maker mindset as a collection of four distinct practices:

1. Encouraging students to pursue projects or activities they feel intrinsically motivated to explore
2. Reinforcing the concept of growth mindset with students, particularly when they are struggling or encountering failure
3. Linking effort and success through the process of revising and iterating on project designs
4. Creating a failure positive environment, where failure is actively embraced, and framed as a beneficial, essential, and commonplace element of learning

My argument is this collective maker mindset directly counteracts the perfectionistic practices and risk aversion behaviors that often emerge in a culture of standardized testing. Making is a rare educational practice that collectively addresses the cognitive, mental, and emotional aspects of learning, and we should begin saying as much. This position guides the core philosophy of the Elon Maker Hub.

C. An Argument Indirectly Supported by Research

Earlier I outlined the four practices that encompass the maker mindset we promote to our students. In short, 1) allowing your intrinsic motivation to guide your interest, 2) embracing a growth mindset (especially during struggle or failure), 3) viewing projects as an ongoing and iterative process, and 4) embracing failure as a key element of learning. Of these, arguably the most important is learning to embrace failure. It is the most challenging practice to develop because it involves overcoming fear, which is an exceptionally powerful emotion. While the first three aspects of our maker mindset promote a specific way of thinking, embracing failure is the only aspect that engages students on an explicitly emotional level.

Fear of failure is formally termed "fear of negative evaluation" (FNE). FNE describes "apprehension about others' evaluations, distress over negative evaluations by others, and the expectation that others would evaluate one negatively" [17]. The fears outlined under *Standardized Testing, Perfectionism, and Unhealthy Learning Habits* all fit within this description. Furthermore, research shows a definitive link between maladaptive perfectionism and fear of negative evaluation [18].

If our students possess some level of FNE, we should treat the cause and not the symptom. In cognitive behavioral therapy (CBT), the most effective treatment of fears and phobias is exposure therapy [19]. In its most basic form, exposure therapy involves exposing a person to the object or situation they fear in a low-to-no danger environment, where they have the option to stop at any point if they feel uncomfortable. This practice is often repeated over time, progressively increasing the amount and intensity of exposure to the source of fear.

A simple argument follows: If our students are afraid of failure, and the most effective CBT treatment for fears and phobias is exposure therapy, then what students need is a structured, low-to-no risk environment where they can experience failure in progressively more intensive ways. This exposure could arguably reduce (and in some cases, eliminate) this fear over time [20].

Making is a low-to-no risk activity. It involves building something you're interested in, learning your current limits (and your ability to grow beyond them), repeatedly failing and revising your attempts, and having these experiences in an environment with a culture of support and non-judgement. When structured and scaffolded properly by an instructor, making represents an ideal approach to exposure ther-

apy for FNE in educational settings. Few other teaching and learning practices can match the high-density value making has for producing healthier mindsets in students.

D. An Opportunity for Research

Evidence exists to support the individual elements of my argument, but does not yet exist to support its conclusion. There is good reason to believe making can permanently establish itself as a high-impact educational practice, but this will require proper supporting research. This research will need to show the effect making as a practice can have on diminishing (and hopefully counteracting) the effects of perfectionistic behavior, as well as promoting positive relationships with failure and learning. While the data does not cohesively exist yet, I hope it will soon.

This fall the Elon Maker Hub will explore new strategies to evolve our assessment, which will be designed to measure the influence making has on behaviors and attitudes towards learning and failure. We encourage our colleagues across the field of making and makerspaces to do the same.

CONCLUSION

Making as an approach to learning and teaching has the potential to become a high-impact educational practice, particularly if its most vigorous supporters are willing to acknowledge the value and utility offered by other research-supported instructional approaches. Complementary practices, such as instructional scaffolding, worked examples, and DI, can be effective avenues for graduating novice and impaired learners into a rich, constructionist environment.

More importantly, I argue these avenues provide a meaningful transition for students struggling under the influence of standardized testing, particularly perfectionistic habits fueled by a fear of negative evaluation. Though the role emotion and fear can play in learning has been explored in research, the role that maker education can play as a coping and intervention strategy has not. I encourage my colleagues within the maker movement to examine this interplay in their future research.

Making is establishing its potential to positively affect change within learning and education. With effort, it can also be positioned as a meaningful approach to dramatically reducing our students' fear of failure, reducing their risk of mental illness, and helping them develop healthy relationships with life and learning.

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