Making People Fail:
Failing to Learn Through Games and Making

Breanne K. Litts, University of Wisconsin-Madison
Dennis Ramirez, University of Wisconsin-Madison

Introduction

From high-stakes measures to tracking students, the structure of the formal education system in America stigmatizes failure as a negative result of the learning process. In traditional school settings, failure is seen as inadequacy based on an inability to meet a specified standard; it is an unfavorable endpoint to learning that should be avoided at all costs. This view of failure has resulted in detrimental tracking systems through which available opportunities are determined by performance.

Within our current education system, because failure is interpreted as an unsuccessful attempt to achieve a learning outcome, poor performance may deny learners access to certain opportunities. Papert (1980) expounds:

> "Our children grow up in a culture permeated with the idea that there are 'smart people' and 'dumb people.'..."As a result, children perceive failure as relegating them either to the group of 'dumb people' or, more often, to a group of people 'dumb at x.'" (p. 43)

The label of failure in education also commonly leads to misidentification of learning disabilities, which has devastating effects on how students are viewed by themselves and others (McDermott, Goldman, & Varenne, 2006). Learners labeled as "not smart", "unsuccessful", or "learning disabled" are also diverted from accessing certain learning opportunities (e.g. taking AP classes) (McDermott & Varenne, 1995). The pressure of this high-stakes system is also breeding a fear of failure in high performing learners (Pope, 2001). In much the same way, these students are under constant pressure to maintain their standings because of the opportunities that are afforded to them. They believe that any sort of failure will render them a less competitive applicant and will limit their opportunities. With this connection between performance and opportunities, it is no surprise that students often have a deep-seated fear of failure in their learning.

Current interpretations of failure focus on the negative implications such as not meeting a desirable, or intended, objective. This interpretation of failure is limiting. Research in the learning sciences suggests that failure is actually a key to innovation and discovery (Dunbar, 1999; Schank, 1977; Kapur, 2013). For example, Kevin Dunbar (1999) studied four biochemistry labs at Stanford University in order to understand how they conducted research. To his surprise, he noted that over half of the experimental results were unexpected. Rather than being classified as failures, researchers analyzed these findings in order to explain the unexpected outcome. This revision lead to refinement of methods, better control of variables, a deeper understanding of the problem, and innovation. (Dunbar, 1999). Ushering learners to avoid failure may come at the cost of innovative risk taking and discovery.

Despite our best efforts to design learning environments, at some point, a learner will fail in it. But failure, in and of itself, is not a bad thing. We argue that what matters more is how we, as educators, plan for that failure, and how we encourage learners to interpret that failure. In this paper, we leverage two areas of educational reform, games and making, to demonstrate a need to broaden our definition of failure and reconceptualize it as an integral part of the learning process. Rather than defining failure as a detrimental endpoint to learning, we discuss how these domains (games and making) expect and design for failure as part of the mastery process. We offer implications for learning and assessment with the hope of sparking a conversation among policymakers, educators, designers of learning environments, and learners.

Failing to learn through games and making

In recent years, scholars have looked to learning through games and making as viable alternatives to traditional learning environments. Thus, using games and making as illustrative examples, we argue that some of the deepest learning happens when we fail, and we, therefore, must adapt our perspective and understanding of the learning process accordingly. Next, we demonstrate a need to broaden our definition of failure and reconceptualize it as an integral part of the learning process. Both games and making are activities that we, as humans, have participated in and learned from for centuries, yet educational reformists have relatively recently taken up these these domains to expand our traditional conceptions of what it means to learn. To gain a better understanding of the breadth and depth of the relationship between failure and learning, we examine these two worlds (games and making) embedded with them.

Learning

As learning scientists, we ascribe to a constructivist perspective of knowledge supporting the idea that meaning is something to be *made* whether through our interactions individually with an environment or socially through culture (Piaget, 1956; Vygotsky, 1978). Moreover, we take up a situated perspective of learning where learners develop understanding in the same context in which it is applied (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991). Accordingly, we believe that learning cannot happen void of context and that we should constantly connect what we learn to real world situations. When considering failure in this way, we immediately run into the crude fact that, in the world, there are sometimes serious consequences for failure. While we recognize that some failures have detrimental consequences, we argue that not all failures are created equally; some failures actually promote learning. Thus, we need to broaden our definition of failure in relationship to learning to realize the rich process of which they are both part.

Games

Dating back to the time when arcades were popular, games have been challenging players to revise strategies and revisit conceptual models in order to progress. In fact, game scholar Jesper Juul theorizes that failure is actually directly related to enjoyment of a game (Juul 2009). This is not to say that you must fail to enjoy a game, but that games somehow allow for failure in a productive way. A growing body of research suggests that digital media, such as games, can provide powerful mechanisms for learning (Steinkuehler, Squire, & Barab, 2012). Specifically, good games encourage players to "take risks, explore, and try new things" by reducing the consequence of failure (Gee, 2006). We argue that games encourage learning through the way they handle failure; games incentivize players to confront an rework their failures (Squire, 2011). Players don't stop playing the game when faced with an undesirable outcome, in fact, "in a game, failure is a good thing" (Gee, 2009).

Making

In response to President Obama's call to design learning environments that "encourage young people to create and build and invent - to be makers of things, not just consumers of things" (The White House, 2009), educational researchers and learning scientists are considering makerspaces as viable alternatives to traditional STEM learning environments. As a result, making and makerspaces have gained traction in more formal and public contexts, and this has materialized as the maker movement (Anderson, 2012). This movement is defined by the mobilization of makers around the world through venues like World Maker Faire, MAKE magazine, and the Internet. Hence, the maker movement is fundamentally changing the way we envision teaching and learning. Particularly, this movement contends that *making*—an active process of building, designing, and innovating with tools and materials to produce shareable artifacts—is a naturally rich and authentic learning process (Martinez & Stager, 2013). As scholars (e.g. Anderson, 2012; Honey & Kanter, 2013; Martinez & Stager, 2013; Sousa & Pilecki, 2013) continue to explore the relationship between making and learning across a variety of contexts, they point to the significance of permitting failure and mistake in making activities.

Broadening our definition of failure

One of the biggest misconceptions of failure is that it is evidence one did not *learn* something correctly. The assumption is that learning is not present in failure. Rather than assuming that *in* our failed state we have not learned, we suggest that *from* our failed state we can learn. In this section, we use examples and data from learning through games research to argue that we need to broaden our definition of failure beyond the dichotomous outcome formula currently used in traditional formal learning environments.

A popular view of game based learning suggests that if goals overlap correctly, completion of the game indicates mastery of the subject (Gee, 2006). This is true when content goals, games goals, and player goals are aligned, but cannot be assumed if they differ. In a game, failure can be considered a function of the goals of the designer and the player. By allowing players to negotiate outcomes and consequences (Juul, 2003), a player's goal can actually differ from that of the games resulting in situations where failure and success may be a matter of perspective. Games offer many ways of playing (Bartle, 1996), including modes of play that involve playing *with* rather than *by* the rules of the system, such as "subversive" play (Tocci, 2012). Some players find success in finding exploits or causing the game to stop functioning. Modding, The popular activity of reprogramming a game to do something other than what it was originally designed to do, is a more explicit way of modifying a game's goals.

Likewise, modding in games parallels hacking in makerspaces. Particularly, makerspaces have redefined hacking from the traditional conception of an exploitative predator taking advantage of weakness for malicious purposes to a more general understanding of using or mashing physical or digital materials together in ways that were not originally intended by the designer. Tinkering, hacking, and making are becoming well-accepted trajectories toward innovations (Levy, 2010; Martinez & Stager, 2013). From projects like hacking a computer mouse and a race car together to create a "mousecar" to modifying mobile phones and launching them into space to take photos of the Earth, hacking is changing the way we engage with the world. Santo (2012) argues that these "hacking literacies" are not only present in makerspaces, but are also vital in our daily lives as we create and make our worlds. Though negatively stigmatized behaviors, like hacking, appear to be evidence of failure to meet certain expectations, in reality they are evidence of a fresh perspective fueling innovation.

When there is a disconnect between the goals of a learner and the goals of a designer, it is a mistake to automatically assume there is a problem. Simply because a learner does not succeed, as defined by the designer, at a given task may not mean they failed. Rather, the performance may be the result of the way the learner chooses to engage with the task. Take, for example, a game of *Super Mario Brothers* (Nintendo, 1985) in which the primary goal of the game, as intended by the designer, is to save the princess. While most players attempt this goal, some may not consider this a success; instead they might define success by a high score or best time. Accordingly, understanding how a learner interprets and interacts with a given task may be the best way to determine if learning objectives have been met.

Failure as a process, not an endpoint.

During the creation of knowledge there are bound to be moments where our understanding doesn't accurately portray the system in question. As Karl Popper suggests, these misconceptions are common and we must therefore subject our understanding to rigorous test of falsification in order to better our understanding of the phenomena (Popper, 1959). If we maintain that knowledge is constructed by the individual, we must allow for incomplete constructs and revisions. In other words, we must allow for failure and in order to learn *from* our failure, we must work *through* it. We argue another misconception of failure is that it is an endpoint. In this section, we use examples from learning through making to demonstration how learning is best conceptualized as an iterative process propelled forward by failure.

Preparation for future learning (Bransford & Schwartz, 1999) and productive failure (Kapur 2013), both offer methods of addressing misconceptions while still allowing for failure. Bransford and Schwartz attempted to draw attention to the deep structure of problems by providing contrasting cases that drew attention to the important similarities, or deep structures. This resulted in less attention being focused on surface features (Bransford & Schwartz, 1999). Kapur, on the other hand, followed a period of discovery learning with direct instruction to address these misconceptions. As Kapur states, "students are rarely able to solve the problems and discover the canonical solutions by themselves...yet this very process can be productive for learning provided an appropriate form of instructional intervention on the targeted concepts is subsequently provided" (Kapur & Bielaczyc, 2012). Both of these approaches lead to fewer misconceptions and gains in learning (Bransford & Schwartz, 1999; Kapur 2013).

In games, preparation for future learning, is reflected in the well ordered problems found in videogames, while productive failure may be found in a game's just in time feedback. Well designed games allow a player to solve similar problems in different contexts in order to draw attention to their commonalities. Game designers take great care to order their problems so that they're difficult, but not impossible for the player to overcome allowing players to use what they learned in other contexts (Schell 2008; Koster 2010). Well ordered problems also serve to keep the player challenged while discouraging player attrition. Failure in a game with well ordered problems, doesn't stop players from playing. Instead, "Game failures led to recursive play, play where students devised a strategy, observed its consequences, and then tried another strategy" (Squire, 2011). Just-in-time feedback (Gee, 2004) allows the learner to play a game without interfering until a certain condition is met. For example, while playing *New Super Mario Brother U* (Nintendo, 2012), if a player had died several times during a level the game offers to show the player how to complete the level. This is similar to the idea behind productive failure in that it allows a player to develop skills and build hypothesis and then presents an exemplary case to address any misconceptions they might have that may be leading to their repeated death. Both of these these approaches are quite common in contemporary games and allows for failure to be an integral part of the learning process.

This iterative approach to learning is not unique to gaming. Papert (1980) describes learning as a process by which a learner builds a deep relationship with knowledge. Much like cultivating a relationship with another human being, it takes time and effort; it requires a commitment to work through challenges. Borrowing a term from computer science, Papert describes debugging as a being the "essence of intellectual activity" in learning (Papert, 1980, xiii).

Put simply, debugging *is* failing. Interestingly, the art of making is its deeply iterative nature.

In makerspaces, the mindset toward failure echos Papert's idea of debugging. In interviews with makers at a local makerspace, they explain that "most people don't give up on the stuff they're working on here" even though "you have the instances where something blows up". Specifically, Jack (1), a member of the makerspace, explains the typical mindset toward failing found in his makerspace:

> "Well, usually what happens is when we work on something, you try something then you fail, you try something and then you fail, and then you just tweak it and work on it and figure stuff out until it eventually does work."

This mindset bleeds into all of the making that happens at this makerspace. For example, another member, Bruce, explains that, "a lot of the [maker] competitions I helped out with… they got critiqued by some of the bigwigs and they know where they messed up and what they can do to fix it, so it's not like an endpoint."

As these makers extrapolate, when approaching learning with this iterative mindset, the failure emerges as a valuable tool on which they rely to "fix" and "tweak" ultimately making a better product. Just as in gaming, mastery is deeply tied to revisions of past failures. In other words, when we are permitted to work *through* our failure, we can learn *from* it.

Implications for assessment

When designing learning environments, whether one realizes it or not, designers are instantiating their beliefs and values about knowledge and learning (Bruer, 1994; Bransford, Brown, & Cocking, 2000). If we take seriously the idea that failure is a productive process from and through which we can learn, then this raises important challenges for assessment. Specifically, broadening our definition of failure and reconceptualizing it as an integral part of the learning process directly shapes and informs the goals we set for learning. Accordingly, we suggest employing assessment tools that identify hot spots of goal misalignment between designer and learner, yet don't immediately penalize the learner for this misalignment. Furthermore, we also propose taking a cooperative approach to developing assessment tools carefully considering *whose* learning goals are being assessed.

Aligning goals in assessment

In games, identifying the difference between activities that fail to achieve the games goals, but serve to further the player's understanding of the subject, or game world, from actions that do not yield a positive result, is the major challenge facing game based assessment. In order to better understand the players of *Fair Play*, a game about implicit bias (GLS, 2013), we collected player's movement data and constructed heatmaps. A player's positional data is recorded and superimposed onto the game map, or UI, and is then color-coded for frequency. Applied to learning games, like *Fair Play*, heatmaps can provide powerful insight into play patterns which can be used to determine or assess player goals and game goals. A final map can reveal patterns like points of interest, points of attrition, unused resources, popularity of NPCs, and locations of interest. This information give us a better idea of what the player did and avoids classifying an intervention as a success or failure based solely on an outcome measure (see Figure 1).

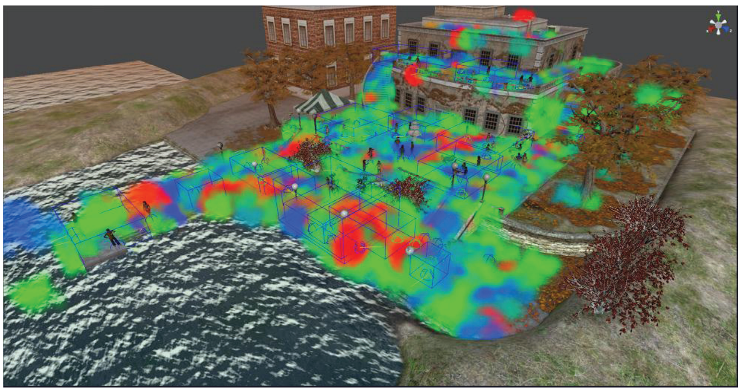

Figure 1: A heatmap created for the educational game, *Fair Play*. This map has recorded multiple users' movements highlighting areas most traveled in red, and least traveled in blue.

If heatmap data is segmented along an outcome variable of interest, say the difference between a pre and post score, researchers can try to identify what places were frequented by low achieving players and what places where frequented by high achieving players (Figure 2). If, for example, most low achieving players seem to be exploring an empty part of the map (perhaps confused by the game's objectives) the game design could place a hint in this location to direct the player towards a more fruitful part of the map. In contrast, the places frequented by high achieving players could indicate interactions that were considered useful by players and efforts could be made to move some of these interactions to the critical path (the parts of the map frequented by all players who finish the game). These patterns can give us key insight into the behavior of players; points of attrition, for example, might reveal a lack of engagement, an especially difficult problem, or an area of confusion.

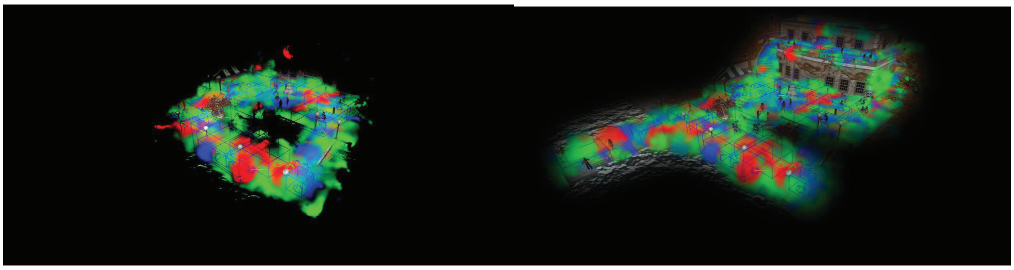

Figure 2: A comparison of low achieving players (left) and high achieving players (right) paths throughout the game Fair Play.

The same information used to create heatmaps can also be made to create predictive models which can serve as vehicles for just-in-time feedback. Positional data can be converted into states within a game, while player movement can be expressed as a transition from one state to another. The resulting data structures can then be analyzed as a network diagram or Markov model. If a sequence is identified as being highly correlated to failure, as determined by the outcome variable in question, the game may show the player a hint similar to the way that Cognitive Tutor offers help to learners it believes are exhibiting misconceptions (Anderson, Corbett, Koedinger, & Pelletier, 1995).

Cooperatively assessing learning

At makerspaces, members often grapple with (re)defining failure. For example, when asked to described a failed project, one member, Charles, explained that he once tried to build a better scuba diving mask, but never finished the project, because it had achieved the goals he set and it wasn't to complete a product, but to learn about the components. This response echoes the ethos found in makerspaces: unfinished/abandoned/broken project does not mean failed project. In applying this approach to assessment, we suggest that cooperatively assessing learning by considering both the designer and learners goals will yield a more accurate picture of learning.

One way to cooperatively assess learning is through understanding the *stance* a learner takes up toward the task. For instance, in a spring break maker program where youth were prompted to "make flow", Alice, a second-grader, was inspired to make a "sugar mill" for her town from a glass jar, cardboard rolls, sugar, tape, and scissors. Darren, another participant, had used these tools earlier to create a modified hourglass—his interpretation of flow. Alice transformed the initial tool use into an artifact that fit into her already existing design and translated the concept of flow from a functional stance (sugar flows through an hourglass) to an artistic stance (Alice explained her sugar mill was art and did not need to work). Tracing her process over time reveals her (self-described) artistic stance in contrast to Darren's functional stance.

With this understanding of stances, we suggest using a stance-specific assessment measures to avoid mislabeling learners attempts as failing. In other words, in the above example, we would assess Alice on whether she achieved her own artistic goals (i.e. does it represent what she intended?) and Darren on whether he assessed his own functional goals (i.e. does it work as he intended?). Appropriately, we would construct these assessments using well-established methods of experts: assess Alice's sugar mill as an artist would and assessing Darren's hourglass as an engineer would. Cooperatively assessing learning in this way gives learners their own voice in the assessment process and, thus, ensures that the assessment aligns with the intended goals of the learner.

Conclusion

The concept of failure as an endpoint is detrimental. To better understand a learner's trajectory, we need to expect and value failure as part of the learning process. We can look to existing learning activities and environments that embrace and encourage failure, like games and making, to inform our re(design) of learning environments. Now, let's make people fail to learn.

Endnotes

(1) Names changed to maintain anonymity

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