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Failing to learn: The impact of failures during making activities

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ABSTRACT

Making is a recent educational phenomenon that is increasingly occurring in schools and informal learning spaces around the world. In this paper we explore data from maker educators about their experiences with failure. We surveyed maker educators about how they view failure happening with youth in their formal and informal programs and how they respond. The results reveal some concrete strategies that seem to show promise for helping educators increase the likelihood that failure experiences for youth can lead to gains in learning and persistence.

1. Introduction

> I have noticed that many of the strongest students academically and who are considered to be 'smart' by their peers often struggle more in creative problem-solving situations. The opposite is often true of many students who are not what is considered 'traditionally' smart. These students excel in a maker context.
>
> − Maker Educator

As expressed in this quote, such a reversal of norms is one reason many feel that making has the strong potential to engage a diverse body of students (Calabrese Barton, Tan, & Greenberg, 2017; Vossoughi & Bevan, 2014) and transform informal (i.e., free-choice, out of school) and formal (i.e., school) education regarding what and how youth learn (Bevan, 2017; Dougherty, 2013; Martin, 2015). In this paper, making involves use of tech-inspired, innovative material and cheap, easy-to-use tools (Martin, Panjwani, & Rusk, 2016) focused on "designing, building, modifying, and/or repurposing material objects, for play or useful ends, oriented toward making a 'product' of some sort that can be used, interacted with, or demonstrated" (Vossoughi & Bevan, 2014, p. 3). As research on making becomes more prominent, evidence suggests that students may gain an understanding of the iterative design process within various making activities such as robotics, digital art production, and circuitry (Bowler, 2014; Halverson, 2013; Hamner et al., 2008; Sheridan et al., 2014), as well as develop 21st Century skills (Buchholz, Shively, Peppler, & Wohlwend, 2014; Gutwill, Hido, & Sindorf, 2015; Peppler, Maltese, Keune, Chang, & Regalla, 2015) creative competence (Saorín et al., 2017) and positive self-concepts and self-images (Norris, 2014).

In the professional sector, making can intersect with innovation, invention, creativity and risk taking (Bersin, Houston, & Kester, 2014; Simpson & Maltese, 2017). In the pursuit to develop profitable products and businesses, individuals and teams cycle through phases of developing, testing, and iterating until a product or business seems viable. Failure, or something not working out as expected, is often a part of the development process or part of refinement after a product or business has launched. Although the term "failure" brings to mind negative associations (e.g., Lottero-Perdue & Parry, 2017), there seems to be a current focus on failure as a

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driver of innovation and development in many professional fields. Catchphrases like “Fail often to succeed sooner” have made numerous headlines in business (e.g., Basulto, 2012; Edmondson, 2011; Schumpeter, 2011) and more recently in education (e.g., Miller, 2015; Sobel, 2014).

In the making context, we define failure broadly as an experience where the result does not match the outcome expected by the maker. We say “expected by the maker” as this might vary between makers’ own expectations and their interpretation of the outcomes expected by an educator or designer of the activity. We think it’s important to understand differences in these expectations between youth and educators. Additionally, we believe there is a range of the scale of failures from minor micro failures (e.g., an LED doesn’t light up the first time it’s wired into a circuit because the legs are reversed) to global failures (i.e., failure of the larger design/system). In our view, failure has a personal component that influences how it is identified and responded to by those experiencing it. Finally, we believe failures are likely to have an additive effect, where multiple small failures can add up to a large effect (e.g., quitting a project). We situate this within the notions of desirable difficulty (Bjork & Bjork, 2011) and productive struggle (Warshauer, 2015) in the sense that educators will need to support youth through these challenges without letting them become stopping points (Kapur, 2016).

Despite how failure is seen as key to innovation in some spheres, the term failure historically, and presently, carries a negative connotation – especially in academic contexts. For example, elementary teachers in a study of an engineering curriculum by Lottero-Perdue and Parry (2017) typically associated failure with non-resilient phrases such as *giving up* or *not successfully meeting the high expectations of others and/or institutional norms*. Furthermore, approximately 84% of the 254 teachers surveyed in their study admitted to rarely using terms such as *failure* or *failing* in their classrooms, if at all. For some, such negative perceptions of failure are accompanied by negative emotional states (e.g., fear, anxiety, depression), low perceptions of self, diminished sense of belonging, and avoidant behaviors (Berry, 1975; Conroy, 2003; Dweck, 2006; Heyd-Metzuyanim, 2015; Nicolaidou & Ainscow, 2005), yet protecting youth from experiencing failure can be harmful in the long run (Dweck, 2006). These risks may be more detrimental for students, specifically females and ethnically diverse individuals in science, technology, engineering, and mathematics (STEM) fields, who are more susceptible to stereotype threat and typically internalize failure (Burke & Mattis, 2007; Koch, Muller, Sieverding, 2008), which may potentially be a factor associated with not pursuing a degree or career in a STEM field (Dweck, 2006).

Although failure may be considered risky and detrimental by some (e.g., Thomas, 2014), others argue that failure is an opportunity to learn from the mistakes and errors of self and others, whether this is on the job or within an educational setting (e.g., Bolinger & Brown, 2015; Kapur, 2008; Slegers et al., 2012; Simpson & Maltese, 2017). Some argue that failure should be embraced for its potential to promote creativity and innovation (Partnership for 21st Century Learning, 2015; Wagner, 2012). Research findings by Kapur (2011, 2014) suggest that engaging in productive exercises of failure within a mathematics classroom may promote greater conceptual understanding, the ability to transfer knowledge to novel problems, and the ability to produce multiple solutions. Tulis and Ainley (2011) noted how students’ positive attitudes after experiencing failures were associated with one’s interest and enjoyment in completing a task. Additionally, educational experiences that involve making, building and tinkering value an iterative process where failure is an expected part of the design cycle and often valued for its knowledge-building potential (Ryoo, Bulalacao, Kekelis, McLeod, & Henriquez, 2015). However, some researchers contend that students in formal educational settings need to be provided with the necessary support and “safe” environment to experience failure; for example, allowing youth to take risks or implementing alternatives to letter-grade assessments (Smith, 2015; Turner, Husman, & Schallert, 2002). We contend that this extends to informal educational settings as well.

In this paper, our primary research goal is to understand how maker educators (i.e., educators who run maker programming for youth and adults) view and identify failure, as well as describe their responses to the failures of youth participating in making activities. Specifically, we address the following two questions:

1 How do maker educators view failure in the context of making?.
2 How do maker educators describe their response, and students’ response, to failure in the context of making?.

We believe that learning more about how educators view these experiences and engage with youth through failure is important because we think it shapes how youth work through and potentially learn from failure. Additionally, this is a critical step in helping us to think about how to work with educators on improving how they notice and respond to failure with the goal of improving learning outcomes for youth.

2. Methods of current study

2.1. Framework

This study is part of a larger project where we seek to understand how maker educators view the role failure plays in making experiences for youth. Our approach is guided by recent research on professional noticing of children’s mathematical thinking (Jacobs, Lamb, & Philipp, 2010). We adapted this to focus on both youths’ and educators’ noticing of failure within making, including the following three components:

1 Attend: Observe moments of failure and be able to describe these moments with supporting evidence. For educators, this component may also include attending to student verbal requests or as a way to not allow failure to occur.
2 Interpret: Make sense of what the youth understands and/or does not understand specific to the failure itself. Likewise, youth need

to consider why they are experiencing failure. For instance, in the case of making activities, this may include content knowledge or use of the equipment.

3 Respond: Actions taken in response to failure. For youth, this may include quitting, trying again, or asking for help from a peer and/or educator. For educators, this may include posing a question, telling the youth what to do next, or fixing the mistake themselves. The key factor in responding is whether or not the response is based on the evidence (attend) and interpretation(s).

Our intention is that by investigating how youth and educators attend to moments of failure, how they interpret what this means, and how they respond, we will be better able to understand the dynamics of each part of the experience and can disentangle moments of failure from response. In the broader study we are collecting data from youths and educators that include surveys, interviews and videos of making activities. Within this paper, we utilize results of our educator survey and focus on the *attend* and *respond* phases as participants described how failures happen within their setting, how experiences with failure are triggered and experienced by youth and how they respond when youth experience failure in making.

2.2. Data collection

As one component of our larger research project, we conducted a survey of maker educators. The survey included both open-ended and Likert-scale items. The open-ended questions elicited responses likely asked as part of an interview, which have been noted for eliciting more than superficial responses (Geer, 1991), avoiding bias in responses since suggestions are not provided, and results that are more diversified (Reja, Manfreda, Hlebec, & Vehovar, 2003). However, we were seeking a larger sample than typical of studies utilizing interview data. Questions on the survey asked about: educational context (space, programming, goals), what type of experiences or activities include failure, views of how failure leads to creativity and innovation, and pedagogical strategies educators use to support youth during moments of struggle. Many of the open-ended questions were written to align with our theoretical framework. For example, the open-ended survey item, “In what ways do you see failure happening in your maker programming?” aligns with Attending component of professional noticing. We included the relevant questions for this study within the body of the findings, as well as within the supplementary resources.

We sought our participants from a range of networks where maker educators communicate. These networks are primarily composed of educators in informal spaces (museums, libraries, out of school programs) or self-identifying formal educators who integrate maker experiences into their classrooms (also including media specialists, librarians, technical education teachers). In addition to posting a solicitation to these networks, we sent out survey solicitations to the Association of Science and Technology Centers’ *Making & Tinkering Community of Practice listserv*, and also sent emails to makerspace (i.e., locations with equipment to allow for making) contacts listed through *The Connectory.org* and through *MakerEd.org.* In our solicitations, we included a description of the study and emphasized the importance of maker educator input to our study, which has been shown to be beneficial to survey response and data quality (Smyth, Dillman, Christian, & McBride, 2009).

2.3. Data analysis

Data analysis involved basic descriptive statistics for closed ended survey responses based on educational contexts and demographic information, as well as sentiment analysis and descriptive coding of essay responses.

We conducted sentiment analysis of the words associated with failure. For this we used the *tm* and *SentimentAnalysis* packages in *R* to process the text data and then compare the responses to lists of positive and negative words within multiple sentiment dictionaries (Liu, Hu, and Cheng, 2005). The *SentimentAnalysis* package calculates a set of sentiment scores by finding the difference between the total number of positive and negative words.

Open-ended responses were analyzed through a descriptive coding process (Saldaña, 2014) as these codes were not based on *a priori* codes and were named as to capture participant descriptions. For example, the response, “The first camp expects to fail and as such doesn't try. The second camp becomes too upset/disappointed by their failures” was coded as *quit* since youth do not try again once experiencing failure, as well as *negative emotions* to describe feelings of being upset and disappointed. The codes varied across the set of open-ended questions as each elicited different information (see Online Resource 1). For example, with the question, *What is your typical response to a student when s/he states, “I need help.”?,* we coded participant responses into the following codes: *Ask them questions, Suggest they seek advice from peer, Suggest they do research,* and *Troubleshoot together*. For example, “talk to another student who had similar problem” was coded as *Suggest they seek advice from peer* as the student was encouraged to seek advice and/or support from another student. Many of the responses were coded for more than one code. For instance, the following was coded as both *Suggest they seek help from peers* and *Suggest they do research.*

> We have a “3 before me” rule. When a student comes to a staff member, they need to have asked 2 of their peers (person on their left and person on their right) and they need to have searched Google. The first response when a youth asks a question for the first time should be “What did you Google?” and our staff might suggest some alternative words to search for if they didn't get the answer they were looking for.

The codes across open-ended survey questions were based on noting frequency in replies as well (Tashakkori & Teddlie, 1998). For the above question, about 11% of the participants noted how their immediate response was to troubleshoot aloud with the student.

In addition, not all responses were coded as the response did not address the question posed. For example, when asked *How do you* *see youth typically respond to failure within a making context?,* one participant responded “We build in time to allow for trial and error.” This response is void of how youth respond, but focused on the role of maker educators in their space allowing trial and error (or failure) to happen. One author coded all responses and developed a codebook (Online Resource 1). Using the codebook, a random sample of 10% of participant responses were coded by another member of the research team. Using Cohen's (1960) kappa for each question, interrater agreement across this sample of responses was .77 (ranging from .46 to 1.00), indicating substantial agreement (Landis & Koch, 1977). As a research team, we discussed disagreements and came to a consensus; developing one additional code for one of the survey questions. This question was recoded. One common disagreement discussed was coding for responses that did not address the question posed. Next, an additional sample of 10% of participant responses were coded by the same member of the research team establishing a Cohen’s kappa of .89, ranging .76 to 1.00 across questions. Falling within .80 and 1.00, we considered this acceptable based on criteria provided by Landis and Koch (1977). Again, disagreements were discussed and changes were made accordingly. Lastly, an additional sample of 30% of responses were coded by an external member of the research team, but someone familiar with making. This additional 30% accumulates to 50% of participant responses being coded for interrater agreement. Cohen’s kappa was established at .84, ranging from .74 to .90 across questions. As noted above, this falls within a satisfactory range as Landis and Koch identified interrater agreement between .80 and 1.00 as *almost perfect.* The first author and the external member of the research team discussed disagreements and consensus was obtained. Disagreements did not lead to a new code.

2.4. Sample

We received usable responses from 107 respondents who self-identified as maker educators. The respondents were 62% Female and 53% reported ages between 35 and 54. Of the respondents who indicated their own race/ethnicity (9% missing), 81% indicated they were Caucasian, 4% identified as Asian, 4% as Black and 3% as Hispanic. The respondents came from organizations in 32 states across the United States that had been offering making-related programming for an average of 5.5 years. We asked them to identify (multiple) common keywords that they would associate with their programming and organization and 74% identified with *Makerspace*, 63% with *STEM*, 57% with *STEAM* and 55% *Other* (mostly maker, engineering or tinkering clubs). Based on the email addresses of respondents and responses to background questions, we estimate that our sample is made up of two thirds informal educators (65%) and one third formal educators.

3. Results

Respondents across all contexts indicated that failure is a common occurrence or that it happens “all the time.” Educators noted that they try to make it very clear to youth that failure is “an integral part of the engineering design process,” and is common when youth or others lack the expertise to make their ideas come to fruition. Despite the frustrations that might come with failure (described below), educators believed that engaging youth in these experiences and supporting them was critical in helping them to troubleshoot and learn from mistakes, as well as transforming youths’ relationship with failure to view these experiences as opportunities for creativity and innovation. In this section, we expound upon these ideas through addressing our research questions. Where pertinent, we include direct quotes from participants to support our findings.

3.1. Research question 1

The purpose of the first research question was to understand how maker educators view failure within the context of making. Respondents framed this broadly and more specific to their makerspace. We asked maker educators what two terms or phrases came to mind when they hear the word *failure* within a making context. The terms most frequently provided were *opportunity, learning,* and *learning opportunity* – accounting for 12% of the total responses without recoding. The next most common grouping that emerged was from *try again*, *iteration*, *prototype*, and *trial and error*, making up nearly 8% of responses. There were not any apparent differences between the terms generated from formal and informal educators. When we ran a basic sentiment analysis in *R*, there was nearly an equal distribution of terms associated with positive and negative sentiment, but skewed toward slightly positive sentiment (399 words; sentiment score based on the *Henry’s finance-specific* dictionary = 0.07, *Quantitative Discourse Analysis Package* dictionary = 0.04, *Loughran-McDonald* dictionary = 0.03, *Harvard IV* dictionary = 0.17 (QDAPDictionaries, 2015; SentimentAnalysis, 2017). This suggests that there is not an overwhelming agreement with the strongly negative connotations that are common when discussing failure and learning. This sentiment was also reflected throughout responses as many participants described the word “failure” as an inaccurate word within the context of making. As one example,

> Failure is a poor word to describe the creative and inventive progression and process toward manifesting a well refined solution. Failure is used by those who really do not understand the essence of how we all make real progress and develop beyond constraints and limits in the real world.

Yet, inherent in this quote is the notion that failure carries a negative connotation and should be avoided as opposed to using the word failure in making contexts to shift from a negative to an opportunity for improvement.

We also asked educators: *When a youth experiences failure within making context, in your experience, what are the various positive and/or negative outcomes?* Responses more frequently fell on the positive side of things (58% of participants), but many educators indicated that there are positive and negative aspects of failure. On the positive side, two common responses were that youth persist and demonstrate resiliency in completing the maker activity (39%), as well as learn from their mistakes (42%), including why something did not work, new techniques, how to use tools, and the notion that failure is part of the process. For example, “Positive outcomes include learning failure as a normal part of most processes before success is reached, being an opportunity to learn about new techniques, technologies, or limitations of materials.” Additionally, respondents indicated that youths attain boosts in self-confidence (14%) and sense of pride and accomplishment in completing the task (18%). For example, “We hear a lot of ‘I did it!’ ‘Look!’ and ‘I am a genius!’ There is definitely more joy in getting something to work when there has been some failure along the way.” Less often stated positive outcomes include the development and/or increase of creativity and innovation (4%), curiosity (3%), and patience (1%).

However, the manifestation of many of these outcomes hinged on whether “success” was eventually attained by meeting an internal or external goal. When goals were not met, quitting the project or program, was the most stated negative outcome (32%). Experiences with failure sometimes invoked negative emotional responses (20%) – frustration and disappointment being the most commonly reported. As such, failure “can be a source of frustration and potentially cause a student to view themselves as not good at science/engineering.” This statement also highlights the idea of failure reaffirming a negative self-image or this self-perception that “I am not good at that” (14%). These views are one’s of personal failure as opposed to failure due to an external locus of control such as the material or constraints due to time.

One educator summed up the general difference between positive and negative outcomes this way: “Failure is when they give up. Success is when they persist.” Framing this as a shift from fixed to growth mindset (Dweck, 2006) might play a role here. As one educator put it, “I think the whole idea is to learn to not see iteration as failure,” while another suggested that “the real value is seeing or recognizing that it's not an end state but just a part of the process. If youth did not experience failure, there wouldn't be an opportunity for this growth.”

Moving beyond general views and outcomes of failure, respondents situated their views of failure within the context of their own space as maker educators. For example, as one component of the survey, maker educators were asked how frequently youth in their programs actively participated in or demonstrated various 21 st Century skills (see Survey). Response options included: *Never, 1–2 times, Weekly,* and *Multiple times/week*. While many of these skills are not singular activities but multifaceted practices, two seem most closely related to failure. The first is: *View failure as an opportunity to learn; understand that creativity and innovation is a long-term, cyclical process of small successes and frequent mistakes*. The other related item, *Deal positively with praise, setbacks, and criticism*, may not be a direct measure of failure, but we feel it is likely similar in nature, particularly the setbacks and criticism. As viewed in Table 1, both items [*View failure* (75%) and *Deal positively* (83%)] had the highest proportions of respondents indicating that youths in their programs actively demonstrated these skills weekly or multiple times per week. The next most common responses included notions of incorporating feedback, designing solutions to problems and the communication of new ideas.

Additionally, respondents noted various ways they see failure happening throughout their maker programming with youth. Failures were broadly attributed to five categories: materials and tools, programming, role of the facilitator(s), the prototype or final

Table 1
21st-Century Skills (% of responses).

Prompt	Never	1–2 Times	Weekly	Multiple Times/Week
Be open and responsive to new and diverse perspectives; incorporate group input and feedback into the work	8	27	49	16
Engage in argument from evidence	20	40	28	12
Articulate thoughts and ideas effectively using oral, written, and nonverbal communication skills in a variety of forms and contexts	7	27	41	25
Plan and carry out investigations	10	29	44	18
Utilize time and manage workload efficiently	8	23	39	30
Assume shared responsibility for collaborative work and value the individual contributions made by each team member	6	27	42	26
Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems	10	38	32	20
Define their own problems to investigate	11	40	34	16
Go beyond basic mastery of skills to explore and expand one's own learning and opportunities to gain expertise	5	36	30	30
Develop and use models	17	29	35	19
Monitor, define, prioritize and complete tasks without direct oversight	12	21	40	27
Develop, implement, and communicate new ideas to others effectively	8	20	47	26
Analyze and interpret data related to their project	18	42	26	14
Work effectively in a climate of ambiguity and changing priorities	10	31	25	34
Solve different kinds of non-familiar problems in both conventional and innovative ways	1	31	41	27
Design solutions to a specific problem or task	2	25	45	28
Incorporate feedback effectively	11	17	50	23
Elaborate, refine, analyze, and evaluate their own ideas in order to improve and maximize creative efforts	6	22	37	35
View failure as an opportunity to learn; understand that creativity	1	24	40	35
Use mathematics and computational thinking	9	24	38	28
Adapt to varied roles, jobs responsibilities, schedules, and contexts	9	36	39	16
Deal positively with praise, setbacks, and criticism	0	17	48	35

Note. Prompts from Partnership for 21st Century Learning (2015). Percentage based on total number responded per prompt.

product, and youths' non-cognitive and cognitive factors. Six participants (6%) attributed failures to the materials and tools; 3D printers being the one tool mentioned by maker educators. Program structure was also noted as a source of failure (14%). Programs were noted as being too exploratory, not working as designed, and limited in time. For instance, "When the program is more self-directed, I have seen more students (middle school, specifically) get frustrated and walk away." As noted by another participant, it takes time to find a balance between too much structure and too little structure as the core of making activities and programs are to elicit creativity and innovation. Moreover, approximately 12% of participants were cognizant of pedagogical failures such as pacing that was too quick, not supporting student thinking and visioning, and adapting to the attributes and skills of different learners.

The most common way participants saw failure happening in making was in prototyping – during the first attempt or subsequent iterations (26%). As an example, "Students are tasked with protecting a raw egg during the flight of a rocket and meeting altitude/flight duration targets. Teams repeatedly fail and need to modify their design." Failure also happens when the final product does not work (11%). But beyond failures being attributed to the object or product, participants saw failures occurring due to youth not reaching personal expectations and goals (22%). "Failure happens when something does not work as expected. Failure also happens when the maker gives up because something does not work as expected." As noted by the latter statement, approximately 7% of participants reported lack of persistence as a failure. Failure also occurred when youth lacked the needed skills and knowledge to troubleshoot and/or finish the project (10%). For instance, "In camp and after school programming, students will also get to a point in their project where they 'get stuck.' They don't have the skills, knowledge, materials, and time to proceed in the direction they are going." Other failures happened when youth did not follow directions, did not ask for help, or did not utilize skills gained in prior projects and activities.

In another question we asked: *Are there particular activities where youths' responses to failure within a making context are more dramatic than others?* Our interest in this issue relates to our belief that more dramatic responses to failure may lead to abandonment of the activity, and in those cases, it is likely that chances for learning or further engagement are diminished or lost. The intensity of responses to failure may also indicate the level of investment a child has in the activity and/or their perspective on what failures can contribute to their making. Responses included a few themes. First, projects that are high tech (e.g., 3D printing, e-textiles, programming, soldering), as well as those that incorporate little to no technology (e.g., woodworking), are responsible for leading to frustration, about 14% and 7% respectively. As an example,

> Working with slower-iterating and more permanent materials. Woodworking and using permanent adhesives like wood glue tend to have the most frustration, as failure might mean a lot of time lost and having to start something over. Electronics wiring also tends to present more frustration as the problem-solving process is more ethereal.

This suggests that high- and low-tech materials and tools may carry equal weight in their potential to promote struggle and frustration.

Second, 28% of respondents suggested that there were material-agnostic issues that led to greater frustration, including if there was going to be a public display of the product, any form of competition, and if part of a group effort. Additionally, 16% of participants noted that the inclusion of any form of time constraint, including limited time at school or a parent needing to move on, as well as limited resources, ramped up the intensity of failures. One respondent stated:

> Anyone who works with 3D printers knows that failure can happen at any time for a variety of reasons. But youth may not take a 3- or 4-hour investment of time into a print that fails at the last part of the print. We talk about the normalcy of that problem, but many youths of today don't have to invest significant amounts of time into any single project.

Regardless of what triggers the dramatic response in youth, approximately 15% of participants indicated that a dramatic response to failure is based mostly on the individual experiencing it as opposed to the activity or project itself. "We've found responses to failure to be highly individual and most often occur when the failure challenges an individual's self-identity." Lastly, about 13% respondents noted how youths' responses to failure were not any different based particular activities; simply stated, "Not that I can tell."

3.2. Research question 2

The intent of this question was to gain an understanding of how maker educators and youth respond to failure(s) in making. As such, we asked participants: *How do you typically respond to youth when they experience failure within a making context? Explain why.* Many (39%) indicated that they address students' experiences with failure by asking questions toward analyzing and reflecting on the failure, in an attempt to get youth thinking of and planning out next steps. For instance, participants noted beginning a conversation with "What's going on?" or "What have you already tried?"; utilizing "probing questions that stimulate inner reflection." One educator framed his/her response this way:

> "Okay, how can I help? Can you explain what is happening? How is that different than what you wanted?" Again, it's about listening. My responses might include questions such as "What would happen if you…?" as a way of leading them towards a solution that I can see, but which I don't simply drop in their laps.

Similarly, reflecting the need to provide support for learners to overcome and learn from challenges beyond their immediate grasp (Vygotsky, 1978), about 11% of participants related their response to the importance of troubleshooting together, while an additional 8% provided suggestions for youth to explore. As an example of the former, "Through a backtracking of steps, we identify together what happened and talk aloud why it might've happened and how to move forward."

Another common response from participants (20%) was to celebrate failures and remind youth that failures are just part of the process and something to learn from. "Turn it into a learning opportunity. Remind them that next time will be better. Even Seymour Cray (inventor of the supercomputer) had failures." Likewise, "encourage them to try again" was also a response to youth's experiences with failure by 19% of respondents. Thus, the goal with these responses was to encourage persistence. Less frequent responses by educators included sharing a personal story of failure and encouraging social interactions with peers.

Respondents were also asked: *What is your typical response to a student when s/he states, "I need help."? Explain why this is your typical response.* One point to note is that asking for help may occur before or after experiencing failure while making, which may explain differences in the responses we received. For example, unlike above, youth are encouraged to seek advice from peers (21%), or from outside sources (9%, e.g., internet), when asking for help as youth are to learn from and teach one another.

> I'll ask the students to be good neighbors and assist. I do stress that the helper should not take over but instead show or talk it through. I have also suggested they search YouTube for a video as there is bound to be something helpful on there!

These two approaches serve three purposes – increase collaboration and self-confidence, and lesson dependence on facilitators.

By far, the most common response to "I need help" is posing questions back to the youth (63%). However, these questions serve the role of having youth articulate what they need help with and/or to find their own solutions to the challenges they face. For instance, "I ask questions about what is going on. Sometimes by talking about it aloud, they come up with their own ideas about how to move forward." Troubleshooting together was another response (11%). Participants are also mindful of how this request for help may depend on the developmental skill level of the youth and can sometimes be addressed through demonstration of a technique or use of a tool. For example, one participant noted how a kindergartener is probably not able to use a screwdriver to loosen a screw.

Although it is a commonly reported strategy, caution is warranted when asking youth to work with one another as there are challenges such as "First attempts at helping one another often mean the student just wants to do it," or "… often if one kid knows (or thinks they know) a little more than the others, they'll kind of monopolize." The issue of students wanting to "fix" the problem for their peers by doing it for them rather than guiding them to a solution seems to fit with more of a *productive success* approach (Kapur, 2016). These scenarios arose from 21% of respondents when asked: *Do you see young people helping one another when they experience a failure? If so, what sort of help do they offer?* The large majority of participants (90%) reported this as a common practice within their makerspace. In these instances of youth-to-youth collaboration, peers offer suggestions and ideas (27%), illustrate what they did through showing their product as an example (15%), provide encouragement and emotional support (11%), and show how to use a tool (4%). For example, "Kids will give as wide of a variety of help as I do. They might point the student to an online resource, show them how they solved a similar problem, direct them to another student who has knowledge in that area, or offer their own suggestions." But as commented by one participant, s/he rarely sees young people helping one another as "I think that expert kids are sick of helping students who are not experts."

When asked *How do you see youth typically respond to failure within a making context?,* the responses seem to manifest in a bimodal distribution across two sets of outcomes: (a) being emotionally frustrated and quitting, and (b) being excited and comfortable with failures and adapting plans (i.e., continue within design process). Yet, participants noted that acceptance of failure is something that comes with time and with coaching around the notion that failure is an integral part of the process when you are learning new material and trying to explore new ideas. For instance,

> In the beginning youth struggle a lot in our programs with the lack of instruction and the exposure to failure. They are waiting for us to tell them the next step in the directions. ... The more exposed they are to failure in a supportive environment, the more confident they become in their ability to move passed it or the less afraid of it they seem to be. Youth who have been with us longer appear to be more motivated for risk taking.

Therefore, we surmise that continuous experiences with failures in a supportive environment may work to shift youths' relationship with failure from an unproductive to productive response, at least within the context of making. But as noted by a few participants (8%), youths' negative emotions and responses to failure in making contexts are due in part to our desire as a society for instant gratification and our drive as an educational institution to produce the right answer. For example, "Our youth are often initially tender about failure because of the constant daily obstacles in life and in media messages that label them and what they do negatively."

4. Discussion and conclusions

In this study, we share data from over 100 maker educators about how they attend and respond to failures with youth in their maker programs. We believe this to be the first paper that evaluates how educators attend to failures in making and makerspace contexts. Maker educators in this study noted or attended to an array of failures including product and process failures (e.g., testing of final product & prototypes) to affective failures (e.g., competition, public display). Educators in this study did not minimalize the negative aspects of failure as they have observed youth quitting activities, experiencing negative emotional states such as frustration, and seeking help prior to engaging in personal reflection. Therefore, some youth, as noted in previous studies (e.g., Heyd-Metzuyanim, 2015), do not view failure as a learning opportunity. However, unlike some educators (Lottero-Perdue & Parry, 2017), maker educators in this study valued and celebrated failure within their makerspaces.

Through their responses to multiple open-ended items it was clear that a primary goal of these maker educators was to help youth deal with failures in a productive way that would help advance their projects, their learning and their persistence in the face of obstacles, similar responses to that emphasized by Kapur (2016) in promoting productive failure. Promoting or even designing for failure was not an explicit part of most educators' activity or program design, but rather a foundational concept inherent in the making process. Their strategies for responding to youth emphasized strategies that reflect the social nature of learning and inquiry-based learning, including: looking to multiple sources for ideas on how to move forward, deep analysis of the made object and any data gained through failure or seeking peer guidance and engaging in conversation through troubleshooting together. Broadly speaking, the strategies that educators employ to improve the chances that failure is not an end state and potentially an opportunity for gaining knowledge, developing skills and engaging in the creative process can be summed up by one educator as:

> We value the learning experience of not succeeding on your first try. We feel that multiple attempts to solve something only enhances the learning experience. We encourage our students to remain positive, keep trying and analyze what went wrong. However, we don't want to be so involved that youth don't have the opportunity to struggle and come up with their own solutions. There are students who get down on themselves or become self-deprecating when they mess up. We work harder with those students to boost their self-esteem in other areas they're successful in. And when they do figure out the correct steps, we set them as an example to their classmates and identify them as a guide for others.

What should an educator do in these instances of failure? Based on the myriad responses provided by educators, there seem to be some shared practices that are promising for improving the learning and affective outcomes for youth. These strategies include:

- Model troubleshooting behavior and minimize strong emotional response to "normalize" failure (e.g., explain how iteration is an integral part of making and an opportunity for growth).
- Minimize constraints (e.g., time) that add stress on projects, as much as possible.
- Resist the urge to step in and directly fix something for youth.
  - Suggest they seek out assistance from peers or online before providing direct assistance.
  - When approaching a youth working on a project, keep your hands in pockets or behind back to minimize likelihood of handling their projects.
- Meet a request for help with questions that can guide youth to find their own set of possible solutions.

While this list is not comprehensive and may not include groundbreaking educational approaches, based on the multiple educators who referenced these strategies as beneficial, we believe they are worth strong consideration by any educator running maker programming with youth.

4.1. Limitations and future research

Given the voluntary nature of our survey, it is quite possible that respondents were biased toward a particular view of failure as a key part of learning. Additionally, we have a greater number of respondents from informal educational contexts and this may influence the results, particularly in considering what is at stake if failure occurs. The sentiment analysis suggests that there is a balance in the responses, but as we continue to explore this topic we will seek out the viewpoints of educators with a range of perspectives. Second, the views of youths involved in making are necessary to validate the findings presented here and to provide great context for how they view failures. We have been collecting these data from youths in our larger study and plan to include in our next phase of analysis.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.tsc.2018.01.003.

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