

Guardians of Practice: A Contextual Inquiry of Failure-Mitigation Strategies within Creative Practices

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ABSTRACT

Failure, whether it be “complete-and-utter” or “a minor setback”, occurs in a variety of different creative practices, yet how it is perceived, handled, and recovered from is a lesser explored design space. Failing to address these perceptions of failure can have psychological repercussions, discourage users from continuing a practice, and form cultural stigma such as those associated with STEM fields. However, mediating practices to develop a culture of resiliency and perseverance is key to sustaining a (lifelong) practice and reshaping pedagogical strategies. In this work, we outline the design space of “guardians”, or elements of a creative practice that mitigate the psychological effects of failure. Through a contextual inquiry, we contribute an inventory of failure-mitigation strategies from a variety of creative disciplines. We synthesize guidelines for the design of new guardians and present a preliminary exploration of guardians for the lasercutting practice – effigies and test tags.

Author Keywords

error mitigation, failure design, creativity, makerspaces

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Errors and mistakes can be a learning opportunity or they can transform into feelings of failure. Mitigating the consequences of error as they occur is essential to preventing users from abandoning practices, developing negative attitudes towards learning, or interpreting error as a reflection upon their own personal worth.

By reframing what constitutes a success, pedagogical methods such as constructivism encourage healthy attitudes towards error and failure, embracing them as part of the learning process [12]. However, not all environments nurture healthy attitudes, and not all users have developed mechanisms for

mitigating the effects of error. Studies within education have identified at least two contrasting types of mindsets: a *growth mindset* where an individual believes they can acquire a skill through effort and work, and a *fixed mindset* where an individual believes that such skills are innate and interpret setbacks as a personal failing [1]. Such negative attitudes can compound along social, economic, and cultural boundaries. In communities of underrepresented minorities, *imposter syndrome*, or the attribution of one’s own mistakes or errors as an indication of a lack of belonging, is markedly more present [9].

Creative practices have developed over time to incorporate mechanisms for approaching, mitigating, and defusing error in constructive and positive ways. Embedded directly into the creative processes, we term such mechanisms “guardians” — these mechanisms may include physical elements like signage that draws attention to avoidable errors, processes that normalize and ritualize common errors, or social structures that are leveraged to offset the psychological harm of error introduced from socio-cultural factors. We believe such mechanisms can be designed into nascent practices to bolster resilience and sustain lifelong practices especially around emerging physical making practices like digital fabrication.

This work aims to better understand how creative practices leverage guardians “in-the-wild” to develop failure-mitigation as an area of research investigation and design practice. We first describe a set of terms and definitions to guide the discussion of failure-mitigation. We then present a contextual inquiry of failure-mitigation strategies used within four creative practices. We synthesize our observations into a guardian design space, extract exemplars to annotate the space, and distill guidelines for navigating, designing, and deploying guardians in failure-prone practices. We conclude with an annotated set of guardian prototypes that operationalize this process within the lasercutting practice, developed in conjunction with interviews from makerspace users, and discuss ethical considerations and social factors in mitigating failure.

TERMS AND DEFINITIONS

Here we define several terms that operationalize how we use failure-mitigation concepts throughout the paper.

- **Practice** - The way in which a technique, strategy, or process is used within a discipline to construct an artifact. We specifically examine a practice within the context of the ideals, tools and materials, and available skills that guide user actions.

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- **Error** - Error describes a state of incorrect or undesirable outcome. We describe error along three contexts: *avoidable* or *human error*, such as mistakes and slips; *unpreventable error*, which is largely tied to machine, tool, material limitations; and *socio-cultural error* that cause outcomes to be deemed undesirable as a result of social norms or cultural barriers such as stigmas, perceptions of self and community, or peer pressure.
- **Failure** - A subjective emotional experience caused by the interpretation of error as unrecoverable that yields negative attitudes towards continuing or pursuing a practice.
- **Guardian** - An artifact, process, or socio-cultural structure that mitigates failure and encourages healthy attitudes towards error. The goal of a guardian is not to prevent errors, but to lessen/redirect/proceduralize the psychological harm from experiencing failure.

RELATED WORK

We describe related work within human factors design and modern practices of failure mitigation.

Error Prevention in HCI

Error-prevention techniques are wide-spread within HCI, drawing from a rich history in avionics. Reason's seminal work [14] offered a combined person and system approach for deconstructing causes of such accidents. This model, also known as the "Swiss Cheese" Error Model describes a series of "error defenses" that mitigate an error trajectory. Human error taxonomies [19] have further classified human error as *mistakes* (those that occur from an inconsistency in a user's mental mode), or *slips* (those that occur from execution or evaluation of a system). In modern UI design practice, Nielsen's heuristics [10] still stand as widely-used error-mitigation strategies, advocating to "eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action." Error prevention is certainly a valuable design practice; however, error prevention is not foolproof, and when error does inevitably happen, HCI has a limited range of techniques to mitigate errors that are unrecoverable.

Practicing failure

Certain creative practices have adopted other failure-mitigation techniques. Fox et al. [2] investigated feminist hackerspaces including a group called Failure Club where the "only true failure is not showing up" which featured community members discussing obstacles in their creative pursuits. Kim et al. [8] developed a taxonomy of creative activities that classified failure by inverting traditional taxonomies focused on success. One such activity included the concept of a failure resume that allowed creators to embrace their failures as learning experiences and provide others with a view of the larger effort behind an individual's practice. Gaver et al. further distills how failure and success may be identified as symptoms along four themes: engagement, reference, accommodation, and surprise and insight [3]. Within user experience design, failure has been suggested as a way of probing the user's mental model through use of purposefully dysfunctional prototypes, or anti-probes [11]. We aim to define the design space for such failure-mitigation techniques through a design ethnography of a wider range of creative practices.

CONTEXTUAL INQUIRY DESIGN

We chose four creative domains in which to study current practices around failure and error: Ceramics, Creative Writing, Electronics, and Improvisational Theatre. These domains were chosen to sample a wide range of practices, from individual to collaborative, physical to digital mediums, and with practitioners ranging from amateurs to professionals.

Practitioners

Since our objective was to understand how specific practices mitigate failure, we employed purposive sampling. Each practitioner was recruited through personal connections or targeted email lists of local creative establishments. Criteria for inclusion was expert knowledge in the discipline and commensurable experience. A profile of our four participants is presented below:

- The **Ceramicist** is a female professional potter with **30 years of experience** who primarily makes functional pottery in a ceramics collective.
- The **Creative Writer** is a female hobbyist fiction writer with **6 years of experience**, primarily engaging in fantasy writing.
- The **Improviser** is a male director and instructor of improv with **30 years of experience**.
- The **Electronics TA** is a male student instructor of an undergraduate introductory electronics class at our university, primarily engaging with students in lab settings, and has been part of teaching staff for **3 semesters**.

While a small sample size, each practitioner contributed to a large, diverse inventory of guardians from their wealth of experience in their respective disciplines.

Methodology

A one-hour contextual inquiry [7] was carried out for each practitioner at their place of work; we documented their physical creative area and approaches towards success, failure, and recovery. For our thematic analysis process, we first transcribed each contextual inquiry, then across five authors performed open-coding [16] on the transcripts.

We reviewed and refined them into a closed set of codes, which we then re-applied to the transcripts. Common themes were synthesized and are presented as guides for future guardian design.

GUARDIAN DESIGN SPACE

Our observation of failure-mitigation strategies across creative disciplines yielded 35 unique guardian strategies. Under the lens of Schön's reflective practice [15], we organized the guardian design space along which type of reflection (i.e. before-action, in-action, on-action) the guardian elicits (Figure 1). The design space is organized along this dimension in order to provide guidelines to support nascent practices, such as those within digital fabrication makerspaces, in order to further develop them into rich reflective design practices. Notably, the most effective and valued guardians could be applied to each type of reflection.

In the following sections we detail each of the three primary reflections within the guardian design space (Figure 1) along

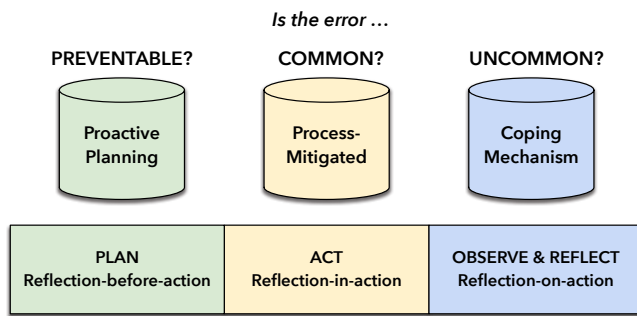


Figure 1. The guardian design space is organized along the dimension of different reflective practices. Appropriate failure-mitigation strategies can be identified along boundaries of perceivability and pervasiveness of the error.

with exemplar guardians observed in the contextual inquiry and finally synthesize design guidelines gained from distilling the full inventory of observed guardians.¹

GUARDIAN: PROACTIVE PLANNING (PP)

While it is difficult to detect an error, **PROACTIVE-PLANNING(PP)** can be employed to incorporate a reflective step in the planning or design stages or a creative task. This type of *reflection-before-action* guardian encourages reflection on design and construction strategies before starting a risky task. Unlike error-prevention strategies which directly integrate this reflective step into the design of the user interface (e.g. in confirmation dialogs), proactive planning guardians aid the user with anticipating avoidable machine or process errors, and reducing the possibility of human errors from recklessness, stress, or anxiety.

Guardian Exemplars

Within our contextual inquiry, we identified proactive planning guardians that existed as tangible elements and as regimented processes.

Firing and glazing tags (ceramics). To aid with firing and glazing tasks, ceramicists use sacrificial pieces, or tags, to evaluate how different kiln settings affect different clay bodies (Figure 2). These tags are typically placed in a readily visible and accessible areas in the studio. These pieces help navigate both the functional and aesthetic space. Rather than mark finished ceramics pieces with unsightly text, the ceramicist develops a key where a pattern (a black texture) is mapped to "CONES 1", a kiln temperature configuration setting. This guardian is particularly effective at preventing avoidable errors: each clay body requires a unique configuration; furthermore, each glaze fires and acquires a unique color and shine based on the clay body. By using tags, the ceramicist is able to offload the cognitive effort needed to retrieve the correct settings; the visibility of the tags facilitates a bricolage practice allowing the ceramicist to build a mental model of how glazes and clay bodies react to firings; lastly, should a piece be successful, the tag becomes inconsequential acting as a type of authorship signature on the ceramics piece; should it fail, the creative work

¹The full inventory is provided as a resource here <https://hybrid-ecologies.github.io/guardians/>

is salvaged as a marker for incorrect settings and refinement of the ceramicist's material mental model.

Incremental development (electronics). A distinct difference between how novices and experts navigate the electronics practice is the art of debugging. The electronicist structures and plans the development of an electronics project incrementally, noting a failure to engage in such a practice as the main source of frustration amongst students learning electronics:

ELECTRONICIST: [Students] will be like "I obviously did everything, should be right, so it's clearly something else." They never think to do unit testing or individual debugging. They start from 0, go to 100%, and test 100%. They never chop it up.

The incremental development process allows for errors to be caught early on and prevent longer term, unparseable errors. It also provides emotional benefit through incremental satisfaction rather than one big disappointment at the end:

ELECTRONICIST: I was pretty used to going from idea to unit test, unit test, unit test, sanity check to make sure everything works, and then put it together, and that actually worked very well for me because I would first test the joystick, realize: "oh wait, half of the angles don't even work", and figure out that I just hooked it up incorrectly. That kind of experience helped me mitigate long-term errors at the very end."

Design Guidelines

Proactive-planning guardians face the distinct challenge of stopping a user's flow. While signage and checklists are the most common types of these guardians, inattentive blindness from rushing to finish a project can prevent them from being noticed in the first place. Behavioral design is an important element when considering how to cause pause for reflection. From the PP guardians observed, we noted the following common strategies:

Develop the senses. Developing and training the senses and body to perceive the state of materials is incredibly valuable, especially to novice practitioners, and a central pillar of the master-apprentice model [5]. While resources often limit the ability to have a master training each and every student, one method of scaling these interactions is to engage peers with similar or proximally similar knowledge bases (i.e. a buddy system), or codify this shared knowledge base by writing guides or improving documentation. When social resources are scarce, one venerable strategy is to use a rapid-prototyping design practice that aims at developing the senses through quick and rapid exposure. Alternatively, one might employ spatializing this cognitive information into the environment. As identified within interaction design, a bricolage practice [18] aims to diversify the materials at hand. In the case of the ceramics firing and glazing tags, this guardian serves as documentation for navigating the functional space of firing clay bodies not only for the original maker but for the other co-inhabitants of a creative space.

Challenge the mental model. In many scenarios, the perceivability of an error is difficult and especially problematic within rapid prototyping practices. Novice users might go step-by-step, developing their ideas on the fly, while more experienced

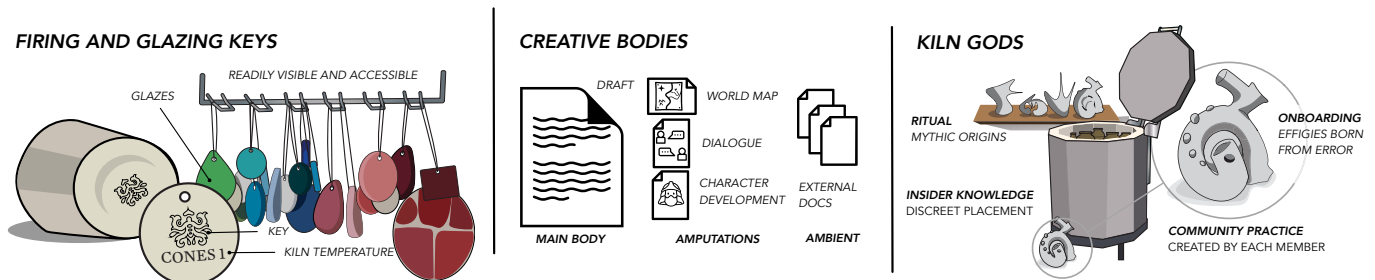


Figure 2. Exemplar guardians. (Left) Ceramics: Kiln settings for different clay bodies are encoded on tags. A key links the setting used to a ceramics piece. Glaze tags are hung in the studio space as a visual record of how different glazes fire on a particular clay body. (Center) Creative writing: Rather than work on one central document, or creative body, creative writers work on smaller elements that may or may not make it into the final creative body. Ambient bodies may be other elements that are not considered part of this creative body, but influence how it takes shape. (Right) Ceramics: Kiln gods as a method of mitigating the fickle nature of the kiln. Derived from mythic origins, kiln gods are typically made at first firing by each member of a ceramics space and placed around the kiln to guard against poor firings.

users will take a broader view of the process to understand and plan for elements they will encounter later in a project. Several strategies observed accept the fallibility of the human hand. Consider, for example, breadboarding in the electronics practice. As a classic translation task, this practice is mostly about adding the right elements in the right positions which is subject to cognitive limitations (e.g. spatial memory, dexterity of the hand). As seen in the exemplar, an incremental development practice tests and verifies sub-components of work despite confidence in its construction. When breaking down a creative work is not possible, *future thinking* can be employed to plan out and consider the multiple forms that the creative work can take (e.g. proposals). When material is cheap but time-intensive, creating multiple copies of an object can be used to play the odds and accept uncertainty in the process.

GUARDIAN: PROCESS-MITIGATED (PM)

There are cognitive limits in "thinking about all the ways things can go wrong," however, that requires us to consider further mitigating the error. If the error is common and pervasive in the practice, such errors can be **PROCESS-MITIGATED(PM)**, where the error is reframed as an essential part of the practice. This type of *reflection-in-action* guardian acts to reframe the practice from destination-centric to journey-centric, particularly in practices where errors are prevalent, widespread, and unavoidable. Consider, for example, a knitting practice that must undo considerable amount of work to correct a misplaced stitch.

Guardian Exemplars

Process-mitigated guardians were more prevalent in elements of a practice that were encountered on a consistent basis. These guardians shared the quality of being a dependable go-to when a practitioner faced a common error.

Evolving rule structures (improv theatre). Within improvisational theatre, rule-based performances are an excellent method of developing improvisational skills. One such game *one-word-at-a-time* requires improvisers to say one word to compose a collective story. Errors are pervasive and unavoidable in this game: the rule is forgotten, a slip occurs, or the comic value of more than one word warrants the rule being broken. Novice improvisers will "pounce" on the offenders, whereas more experienced improvisers will recognize it as

part of the practice. The larger objective is to play, "move forward, with everyone's joyful participation", and understand "rules are scaffolds to get you through vulnerability, fear, and relax, breathe, and see" (**IMPROVISER**).

Reclaiming work (ceramics). For a ceramicist, errors from working with clay are rampant. As such, the methods for reclaiming, reframing, or learning from "failed" pieces is extensive:

CERAMICIST: If they are really really bad and they're still in the clay form, you can reconstitute the clay. I actually have a pugmill and clay mixer ... you can throw it in the bucket and bring it back to life again... If it's gone through the bisque firing, there's not much you can do but throw it away. If it's gone through the glaze firing and it's no good (like it has a pinhole or a slight crack or the glaze is a little bit crazed), we have a second sale every May and we sell those at reduced prices.

The vehicle of a "seconds sale" for pieces that did not quite reach an ideal state also serves as a place for free and open knowledge exchange and advice amongst other ceramicist in the guild. It also acts as reducing the barriers to creative exploration:

CERAMICIST I'll do something on a test-tile and it looks really great on this size. I'll do it on a bigger size and it won't work, so I'll just edit that out. I just won't use that design again, or it'll end up in the "seconds sale". Sometimes we put things out in the gallery and somebody will come by and be like, 'I really like the direction that you're going in, I really like these pieces, I think you should do more of them.'

Ritual(creative writing). Writer's block, or the psychological inhibition whereby an author loses the ability to proceed with a work, is an integral part of the practice. A ritualized practice, or the repeating of a process or activity in a regular, established way can act as a guardian by cementing an aspect of practice as necessary, and encourage a sustainable, growth-based practice. The writer establishes a Saturday morning ritual, drinking the same cup of tea, and setting aside an hour of her day.

This ritual helps mitigate issues around writer's block, reducing the conscious effort and distress from "finding time" and perceiving herself as prioritizing writing over work and social

obligations. By ritualizing the process, the guardian addresses possible factors that may influence writers block as well as reduce the cognitive and emotional effort of planning to instead simply prioritize the act of writing.

Design Guidelines

The common errors observed in several practices were often viewed as a shared burden to "commiserate around". These guardians varied more widely in form and function, however they did share a quality of reframing errors as progress.

Ritualize feedback. As a central element of creative practice, reflective practices have been observed in a variety of disciplines [15]. Such practices introduce an incremental strategy that makes a change to a creative body, and steps back to observe external elements react and respond to this stimuli. This is particularly powerful when ritualizing tedious or error-prone processes. Some practices do not have such an immediate, pleasing result, which is especially problematic when novice users anticipate "immediate gratification from their actions" [17]. One strategy aims to make a stimuli or practice more enjoyable to work with, or to further refine the practice to make the effort worth the results. Such reflective practices are mechanisms for encouraging continuous progress as a way to stay engaged through the creation process despite the presence of obstacles and hurdles.

GUARDIAN: COPING MECHANISMS (CM)

Uncommon errors, or ones that are unique to the individual and situation, can be mitigated through a **COPING-MECHANISM(CM)** that aims to normalize and reframe error. This type of *reflection-on-action* guardian acts to cope with the psychological, cultural, or social aspects of error by reframing it as a positive element of a practice.

Guardian Exemplars

Kiln gods (ceramics). Firing clay is a tacit process and although electric kilns have improved success rates, environmental variables can still effect the outcomes of a piece. Kiln gods (Figure 2) are effigies, usually created during the on-boarding phase or first firing of the kiln (a christening of sorts). They are created by the community of ceramicists that use the kiln and space, and typically placed at the base of the kiln of overlooking it. The effigies oversee the firing of pieces; when a firing fails, blame is offset to the effigy: "the kiln god was not happy with me today". While it is unknown whether the kiln god plays a role in the success of a firing, the shared practice amongst community members acts as a connective element and strengthens studio culture.

Bodies and amputations (creative writing). This guardian refers to a decomposition and modularization of a creative body of work (Figure 2). We use the term amputation to refer to parts of a creative practice that may or may not be integrated into a main body of work. Within creative writing, a writer may have a document that contains more solidified chapters and storylines. An amputation may be a character dialogue script that is used to develop a character's personality, and may or may be integrated into the final manuscript. Distributing the creative body allows for creative pressure to be reduced.

WRITER: I used to write everything in one giant document, and then eventually I figured out that it was overwhelming because it felt so finalized, so at some point in my process I started just opening new documents I wanted to write a new scene. It gave me a lot of peace of mind to know that it wasn't this thing that was being put into what looked like the official document.

The format of amputations matter as well. Formalizing them too strictly can limit the creative freedom they provide to rearrange and reconceptualize their contributions. This reduced creative pressure reduces the criteria needed for work to be considered a "success" and "provides a home for beloved pieces" that have not yet been integrated, without the pressure to either destroy or immediately fix them.

WRITER: I save my documents by date, so I don't save them by "Chapter I", "Chapter II", and I feel like this also makes a little more free if I want to paste things together into different formats later, as opposed constraining myself to saving it by "1, 2, 3, 4, 5, 6".

These amputations free the writer to arrange creatively, work non-linearly, and to healthily manage the emotional burdens that come with the expectations of a final piece.

Design Guidelines

Coping mechanism guardians were more prevalent in solitary creative tasks and shared the quality of diffusing failure.

Mitigating risk. Certain practices carry a particularly high *workmanship of risk*, or the "workmanship using any kind of technique or apparatus, in which the quality of the result is not predetermined but depends on the judgment, dexterity and care which the maker exercises as he works" [13]. For techniques and apparatuses that depend so much on an individual's personal skill, there is also significant risk of error being internalized as a personal failing. Strategies around mitigating errors can be as simple as reducing the economic costs of working with a material or apparatus, however this is a resource-dependent strategy. Salvage and re-use strategies can be employed in such contexts, particularly useful for reinforcing "partial successes."

Offset psychological harm. While a major aim of creative works is self-expression, in situations where the maker is not sufficiently comfortable with a process, working on a personal creative work can be detrimental during early stages of learning. Strategies that offset psychological harm include depersonalizing a training piece or offsetting the failure to a third actor - healthy attitudes dictate that this should be an element of the creative practice, as opposed to actual people. The most relevant example is the use of kiln gods in ceramics practices [4]. Embodying such psychological harm can act as an external sink for stressful emotions and uncomfortable aspects of a practice.

Reframe communal perceptions of failure. In many scenarios, failure is embedded in the practice itself. Social perceptions of demonstrating ease and mastery and hiding or downplaying errors demarcate the boundary between expert and novice users. To emphasize the existence of a robust and supportive community, communities can showcase both successes and errors deemed failures with the aim of normalizing error. At-

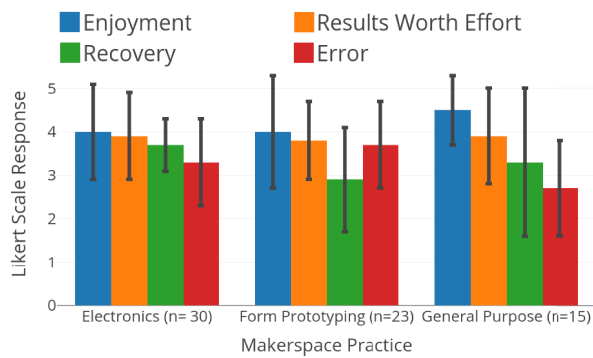


Figure 4. Results from interviews with makerspace members. Users were asked to cluster 19 machines, tools, and processes into groups based on criteria of enjoyment, recovery, results worth effort, and error. Items are clustered; only items that were familiar to the user were counted in the quantitative analysis.

tributions are particularly powerful in attributing social capital to an error (e.g. even the lab manager makes mistakes). Such galleries can showcase a variety of outcomes, processes, and creators and provide opportunities for conversation and peer learning. Alternatively, framing discussions and documentation around working through an error can develop cultures of resiliency.

Leverage social structures. Communities can provide insight, encouragement, support, and assistance that are neglected or absent from a practice. One strategy is to build or enhance community around processes or tools, helping users to feel like a part of a larger whole. This may involve instigating communal projects, establishing regular critiques, or developing a practice of exposing personal work to a wider audience.

The guardian design space we propose is meant to aid practitioners when designing guardians, and should be considered holistically; practitioners should not limit their focus to just one theme or strategy, but consider all of them in tandem. Errors are multidimensional and do not fit perfectly in easy categories. While a particular error might be, for example, incorrect tool settings (an avoidable error), this slip may have been caused by the social pressure of an unexpected visitor (an uncommon error). The ambiguity of deciding which guardian process to use is reflected in a case study within the lasercutting practice, detailed in the following section.

CASE STUDY: MAKERSPACE GUARDIAN DESIGN

In this section, we describe a case study that describes the process of developing two prototype guardians for the lasercutting practice. We first describe observational studies that motivate the focus on lasercutting, and then describe the design process employing guardian design guidelines (Figure 1).

Observational study and interviews

While no makerspace is the same, one distinguishing characteristic is that every makerspace supports more than one practice. The aim of this study was to identify a process and group that would benefit from the introduction of a guardian into the practice. To better understand the ecosystem of practices and how they interact with each other, we conducted a

fly-on-the-wall (FOTW) [6] observation study on four university makerspaces, followed by four 30-minute semi-structured interviews with users (2 male, 2 female, avg. 22 years) with 1-3 years of experience working within these makerspaces.

The interviews were structured as follows:

- *Likert Scale Card Sort Questionnaire:* Participants were presented with a series of cards depicting images of 19 machines, tools, or processes (MTPs) in the makerspaces. Participants first culled the cards to the MTPs that they were familiar with, asked a series of semantically-anchored 5-point Likert questions relating to error, enjoyment, support, and worth and asked to cluster the cards according to their Likert rating. A cluster, for example, would form around MTPs that were perceived with high error. We would then probe as to what criteria constituted for the user to place an MTP in that cluster.
- *Source of Support Card Sort:* Participants were asked to cluster MTPs based on where they would most likely seek support in case of error. We provided a closed-set of sources derived along media-boundaries, including "instructor/lab manager," "peers," "video resource," "image resource," and "text resource."
- *Cultural Perceptions:* Participants were probed on their perceptions of failure, success, and makerspace culture.

Results

During our observational study and interviews, we found that students working on class projects were likely to offset blame to instructional design or support structures ("it's my TA's fault for explaining this poorly!") as compared to personal projects where psychological discomfort occurs without this ability to offset blame to a third-party. In our interviews, we frequently heard evidence internalizing the belief that their intellectual capability was to blame; thus, we decided to focus the scope of this case study on one particular makerspace in our community, which we will call Makerspace A. Users of Makerspace A tended to focus more on personal projects instead of assigned classwork. Additionally, we targeted tools that elicited interaction with lab managers or other users.

Ratings from the card-sort are depicted in Figure 4; the 19 original MTPs were separated along the dimension of practice - 8 electronics (e.g. multimeter), 7 form prototyping (e.g. lasercutting, 3D printing), and 4 general use (e.g. scissors, drill, glue gun) - and clustered. Although there was a potential for 76 data points, only MTPs that were familiar to students were counted.

Based on the Likert task, form prototyping tools were associated with being the least recoverable. In this cluster, laser-cutter stood out as being rated "most error-prone" (4.1), yet "most recoverable" (3.9). It also received high scores for "enjoyable" (4.6) and "worthwhile" (4.8), with lab managers as the main source of support.

With these factors in mind, we chose to design prototype guardians for the laser cutter in this particular makerspace. In the next section, we describe two guardian prototypes that we designed and constructed to embody several themes of our guardian philosophy.

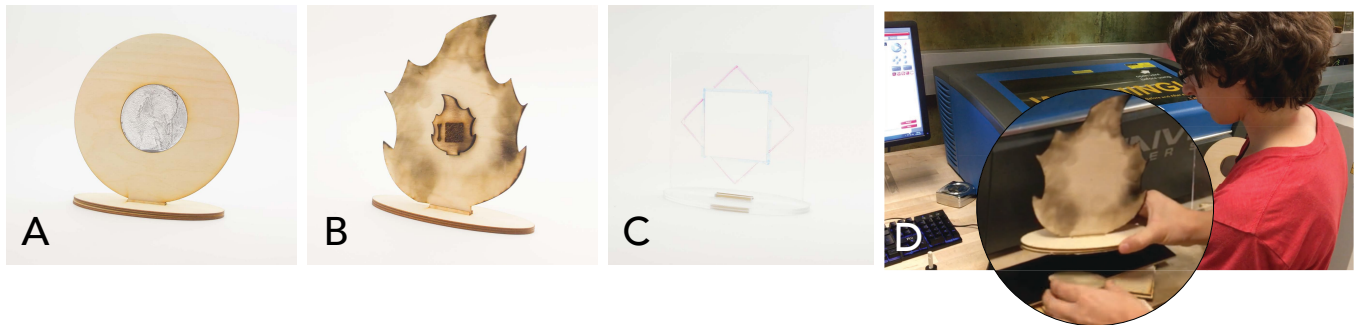


Figure 3. Effigies of Lasercutting. A) This effigy guards the act of firing the lasercutter with a dirty lens or mirror. The resulting lens wipes is used as an offering. B) This effigy guards the act of causing a laser cutter fire from improper settings. Burnt or singed artifacts are used as an offering. C) As transparent and missable as improper design settings, this guardian guards the act of wrong cut/engrave/score configurations. D) A depiction of interaction with the effigies during a lasercutting mishap.

Effigies

Description. The first laser cutter guardian prototype is a set of "Effigies." These effigies each represent a particular type of common error when using a laser cutter; together they become a guardian for coping with unavoidable bad laser cutter results.

The effigies are placed near the laser cutter. When a cut comes out imperfect, instead of throwing it in the trash or sulking at the imperfection, the user takes the part and offers it to the effigies. Finding the appropriate effigy encourages reflection on what went wrong. The user leaves the part with the effigy, reframing the mistake as an offering, rather than as trash. The user can look at previous offerings, getting a sense for how many other people have made the same mistake. If the user doesn't know the root cause of the error, examining other 'offerings' may provide some insight. For the lab manager, the community, and new users in particular, the effigies give a sense of what errors are the most common. These insights can be both practical for future training interventions and community-building. Rather than feeling like a mistake is alienating or shameful, a mistake marks them as an experienced member of the community.

Rationale Effigies reflect strategies from **COPING-MECHANISM** and **PROCESS-MITIGATED** guardians:

- **OFFSET PSYCHOLOGICAL HARM:** When a cutting error occurs, the evidence of the error is captured as an offering to the effigy. The collected history has no names associated with the pieces; the mistake does not need to be claimed and can remain anonymous. The effigy further reclaims this failed piece as a useful element to the user and community, allowing for a mental model of the lasercutter design space to be further developed and serve as a starting point for conversations about what went wrong rather than going in the trash as waste. Embodied failures can support a self-directed learning process where creators of all levels deeply examine both successes and failures.
- **REFRAME COMMUNAL FAILURE:** The public visibility of the guardian offerings serve as a physical visualization that everyone makes these errors; in contributing to the effigies, a shared context arises where peers which engage with the same effigy can commiserate or offer advice.

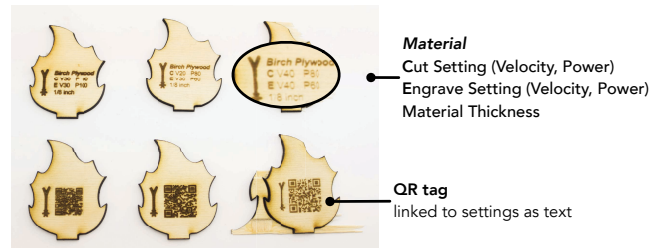


Figure 5. Test Tags Guardian. Six examples tests tags with laser-cutter engraved configuration settings (top row) or linked to a QR code (bottom row). Even the unsuccessful settings serve as a guide for lasercutters as they navigate the power/velocity space. QR codes or more aesthetic encodings can serve as a reference for finished pieces.

- **RITUALIZE FEEDBACK:** The shared space between the effigies and the lasercutter acts as a method of ritualizing the process and have users interact with these failure logs within each firing of the lasercutter, framing the process as a chance for learning through mistakes and context.

In allowing the process to mitigate the effects, we reflect the theme of ritualizing behaviors. Each time a mistake occurs, the user interacts with the effigies. In this way processing an error becomes a natural, required part of the process, as much as turning on the laser cutter or measuring stock. This mitigates the emotional valence of dealing with a mistake.

Tags

Description. The second laser cutter guardian is *Test Tags* (Figure 5). The tags burn the settings used to cut a part into the part itself, connecting the metadata to the resulting object in a physical, permanent way. The user can use these tags to create test cuts that become an ever-growing reference library of successful and unsuccessful settings for various purposes and materials.

Rationale. Failed pieces are often discarded and successful pieces are not transparent in the careful navigation of lasercutting settings. This guardian aims at externalizing this information.

- **REFRAME COMMUNAL FAILURE:** A failed piece may be seen instead as a data-driven exploration of the available settings space. Even pieces that failed provide useful metadata

about settings, materials, and the tool's capabilities that is beneficial to the user and larger community.

- **DEVELOP THE SENSES:** By simplifying the data-collection developing a practice where users are conscious of lasercutter settings, participants are engaging in an iterative design process. When examining a finished piece, the laser settings are available immediately at-hand, there's minimal separation between artifact and necessary metadata. By embedding crucial parts of the process into the object, this supports a long-term, asynchronous creative process.

DISCUSSION

Our ethnographic study covered a range of creative practices and extracted three high-level guardian types to guide the design of future guardians of practice. While we touch on such design guidelines, there are several factors that need to be considered which we outline in this discussion.

Ethical considerations of preventing failure

While a central aim of a guardian is to mitigate perceptions of failure, there are side-effects to not experiencing failure. For example, one strategy for incorporating errors as a natural part of the creative process might elect for epistemic actions; while such actions can greatly support exploratory processes, it can also prevent users from linking theoretical knowledge if they can just "brute force" it. In fact, this was a major concern within the electronics lab - having a teaching assistant in the room was enough for students to elicit help rather than engaging and debugging their electronics design independently. Guardians should not be seen as the arbiter of healthy lab community, but merely facilitating mental processes in a healthy and sustainable direction.

Gatekeeping behaviors

Guardians have the potential to become gatekeepers, a negative consequence that must be deliberately and actively prevented. In ceramics, knowledge of and the creation of one's own kiln god increases feelings of belonging in the ceramics community; however becoming privy to such knowledge can act as membership to a club [4]. While such knowledge can support an in-group it can easily morph into knowledge that enforces an out-group. Technological practices already have significant issues with gatekeeping; the introduction of guardians must be carefully designed to welcome newcomers rather than exclude them.

Community-based participatory design

Each community is unique, with its own norms, context, and culture. While guardian themes cross many boundaries, particular instantiations are unique to their setting. Therefore guardians must be designed for a particular community, and for best results, by that community itself. Successful community norms develop from within, rather than being imposed from the outside; as guardians change community norms, they must also follow. An imposed guardian may never be adopted, or even if forced into a practice, may not achieve the desired effect.

LIMITATIONS AND FUTURE WORK

There are many creative practices in the world, each with its own approaches to failure. Even within a practice, variations in location, culture, and individual preference will shape these approaches. A broader set of ethnographies may reveal further insights into guardians and themes. In order to generate and further refine the guardian design space, future work in this area can more deeply study creative practices through observing participants in the field for longer periods of time, or sampling a larger set of creative practices and cultures.

The guardian prototypes presented in this work serve as illustrative examples for the guardian guidelines. The next step is to perform longitudinal user study on constructed guardians deployed in a makerspace, to investigate their effects on attitudes towards failure, overall self-efficacy, community norms, and success in the makerspace setting. As many creative practices have long histories with their own guardians, the adoption process for new, constructed guardians is an open question. While our study particularly focused on maker practices, guardians as a failure-mitigation technique can be embraced by a variety of practices such as engineering or social practices. The potential to develop healthy attitudes around failure is central to developing new reflective practices, improve confidence and resiliency, and spur creativity and exploration of new materials, methods, and tools by a broader audience of makers.

CONCLUSION

In this paper we have explored a new methodology for shaping attitudes towards failure in technological practices. In an ethnographic study of creative practices, we extracted guardians that encourage healthy attitudes towards failure, organized the guardian design space along the dimension of reflection, annotated the space with observed exemplar guardians, and synthesized these into actionable strategies for designing guardians for new practices. We provide a case study of two guardian prototypes for the laser cutting practice to enable other designers and creative practitioners to apply this methodology in their own settings and demonstrate that guardians can be powerful elements of a practice for sustaining practice for any creative setting.

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