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Socialization through stories of disaster in engineering laboratories

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Abstract
The initiation of novices into research communities relies on the communication of tacit knowledge, behavioral norms and moral values. Much of this instruction happens informally, as messages subtly embedded in everyday interactions. This study uses participant-observation and interviews to investigate how engineers socialize future engineers by studying how undergraduate students who work in an engineering laboratory learn their research community's social and technical norms. I found that a key method of conveying knowledge about social behavior and technical practices is the narration of the experience of mistakes and failures. As a powerful tool of socialization, these 'disaster stories' contain messages of self-deprecation, humility, teamwork, and mutual learning. They are most often told by the principal investigator or a graduate student to an undergraduate student and thus generously offer novices the opportunity to learn vicariously through more experienced engineers' errors. Disaster stories can reduce hierarchy, normalize learning through mistakes, and build relationships among workers through the sharing of humbling personal struggles. The stories promote collaboration, a sense of belonging, and the value of continuous learning for all the community's members. They demonstrate the power of storytelling in the acquisition of tacit social and technical knowledge.

Keywords
socialization, laboratory culture, discourse, higher education, gender, vicarious learning

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A graduate student carefully handed an undergraduate a long thin glass tube and a length of stiff wire that was just barely thinner than the tube. Raising his voice over the incessant hums and gentle bangs of the laboratory's machinery, the graduate student, Kenny, asked the undergraduate, Gretchen, to thread the wire through the tube to assemble a component for their experiment. (All names are pseudonyms.) Gretchen held the delicate tube in one hand and the trembling wire in the other and, squinting, aimed them at each other in midair. Kenny advised, 'I would do it on a workbench or you're going to bend the wire. The first few times I did this I bent the wire.' He could have just given her a command, as a higher-status and more expert researcher. Instead, Kenny offered friendly advice justified by a story about his own specific failure to complete this task. This admission of error contributes to a novice's learning and a research community's culture in several important ways, including clarifying how to (not) do a technique, sharing knowledge gained from experience, reducing hierarchy through self-deprecation, and making instructions memorable by justifying them through a personal story of bad results. By sharing what had happened to him, Kenny generously saved Gretchen the work of learning that lesson by making her own mistakes. Perhaps his story deserves at least partial credit for Gretchen's success in threading the wire – unbent – through the tube as it lay on a workbench.

Storytelling is a subtle and powerful method of socialization. Stories explicitly convey a community's beliefs about good practices and behavior, as well as implicit ideas about appropriate moral values, priorities, and social roles. Telling stories also creates space for social interactions, building relationships between a storyteller and listeners. Telling stories to children is an important and possibly universal pedagogical tool (e.g., Miller and Moore, 1989). The same approach, perhaps surprisingly, is true for training novices in expert, high-skill research communities in science and engineering. How researchers tell stories to students, and what kinds of stories they tell, are revealing indicators of how a community defines itself, its work, and its members. How a community shares these expectations with learners, as potential future members, is a crucial foundation for learners' experience of the community and, accordingly, the strength of their sense of belonging in it.

This article analyzes an unusual genre of storytelling, the pedagogical recounting of personal failures, that I observed in an engineering research group in the United States. The principal investigator (PI), a tenured professor whom I call Kate, and her graduate students frame

these stories as specific, practical warnings inspired by the teller's own experiences in research. They recount them in situations of informal teaching and learning, such as meetings and collaborative benchwork. These anecdotes are often told with self-deprecating humor and humility with the theme, 'don't do what I did'. The stories never relate 'disasters' in the sense of physical harm or career-ending mistakes. Rather, they feature relatively small and everyday setbacks that the tellers playfully portray as seemingly insurmountable catastrophes. I aim to capture the playfulness and mock-catastrophism of the genre with the name 'disaster stories'. Kate and her graduate students typically tell disaster stories to undergraduate workers, the group's most novice learners. The undergraduates react to disaster stories with attentive listening, empathy, and sometimes relief. The stories of laboratory woe indicate that even experienced researchers make mistakes and that they want to help others avoid the same fate. I argue that telling disaster stories, by inviting novices to learn from the mistakes and failures of experts, encourages and supports a collaborative culture. As I detail in the following section, this differs in important ways from laboratories and scientific workplaces where stories of competition and heroic individual successes prevail (e.g., Hu et al., 2012; Traweek, 1988). That is, disaster stories flow from and contribute to a workplace culture that embraces a particular kind of learning, one that I argue is less hierarchical.

I first define what I call 'vicarious learning' in the context of literature on storytelling and socialization in research communities. I then describe several occurrences of disaster stories I observed in my ethnography. I argue that these stories shape the group's social structure by reducing hierarchy, encouraging knowledge-sharing, and building trusting relationships. I conclude by suggesting that inviting novices to learn vicariously through experts' failures both conveys and constructs memorable social and technical knowledge, and therefore constitutes a crucial component of a community's worldview, identity, practices, and social order.

Stories as socialization

Science and technology studies' (STS) foundational accounts of socialization and tacit knowledge acquisition emphasize hands-on practice and interactions with more experienced practitioners (e.g., Collins, 1974, 2010; Lave and Wenger, 1991). As these studies have shown, novices acquire crucial tacit knowledge by immersion in a group. Only through 'legitimate peripheral participation' in a 'community of practice' can learners gain the practical skills and

the social knowledge required to be accepted as members of that community (Lave and Wenger, 1991). This immersion and participation rely, I suggest, on interpreting a community's stories and, eventually, telling one's own stories in the same genre. That is, storytelling is an important and often overlooked medium for both constructing a community's knowledge and sharing it with learners. Stories are powerful tools of socialization into research cultures because they can convey implicit social norms and expectations, as well as explicit technical instructions. Telling stories of mistakes to help others avoid them is an example of a broader category of opportunities for novices to learn from someone else's personal experience, or what I call 'vicarious learning'.

Workers in science and engineering invite vicarious learning when experienced workers share expertise and build relationships by telling novices stories about the community's work and career paths as well as their own individual experiences (Lave and Wenger, 1991; Swap et al., 2001; Trice, 1993). Stories told to learners, as potential future members, differ from stories told to outsiders. For example, scientists tend to tell outsiders, such as funders, children, and the general public, stories that omit failures and instead portray their research as successful, fun, driven by social problems, and with significant potential impact (Felt and Fochler, 2013). In comparison, stories told to science learners often communicate scientists' own authentic view of their work, including that it is plagued by delay, failure and monotonous routines (Felt and Fochler, 2013: 84). Vicarious learning is thus a way of building trust and relationships, making it a markedly different socialization strategy from impersonal instruction in classroom lectures and textbooks.

Stories as sociotechnical knowledge

Most communities share stories about individual experiences of their mutual work. These are often told for entertainment and community-building, in addition to didactic instruction. For example, while conducting surgery, surgeons tell 'war stories' about how they have reacted to unexpected complications (Hu et al., 2012). War stories are arguably more memorable and convincing due to their personal connection, because stories that relate someone else's experience (rather than the teller's own) are often a combination of fact and oft-repeated legend (Trice, 1993: 83). In war stories, surgeons' intentions may include conveying technical knowledge to lower-status staff including residents, medical students, technicians, and nurses. Such technical advice is inseparably embedded in implicit messages about social norms. For

example, these stories portray the teller as an individualistic hero, genius and role model even in cases of disaster. Like success stories and disaster stories, war stories are told *down* the hierarchy, to learners and other lower-status workers, thereby enacting a social order and asserting the teller's power over the listener. They also help a community of workers define themselves as distinct from other communities (e.g., surgeons from other operating room staff) and therefore legitimate in their area of expertise. To serve a similar group-legitimating function, Dingwall (1977) noted workers telling 'atrocity stories' about the incompetence of similar or competing professions. Atrocity stories are primarily told to students who are then expected to embrace and enact the stories' principles of group identity and inter-profession relations, a cycle that may make these stories 'self-fulfilling' (Dingwall, 1977: 385). Repair technicians tell 'war stories' for an additional, epistemic reason: They recount unusual problems that they or other technicians have encountered and solved as 'an apt tool for the community memory' (Orr, 1986: 67). These technicians create an oral tradition of problem-solving anecdotes that function as a communal how-to guide. Personal stories, then, can be tools of community-building and technique documentation.

Similarly, scientists and technicians tell stories to define appropriate technical practices and social norms. Nelson (2018) found that technicians in behavioral genetics laboratories convey technical instructions through narratives of how their actions affect lab mice and thus their experiments' results. For example, one technician told Nelson (2018: 116) that she noticed that mice react to her emotions, so she is careful to calm herself down before entering the mouse rooms. The lab's scientists are skeptical of the technicians' stories, perhaps because they find personal experience to be insufficient evidence or perhaps because they consider technicians lower in status. In another example of using stories to teach technical practices, Sims (2005: 341, 347) found that scientists and technicians in a high-voltage plasma physics laboratory tell stories about true lab disasters, such as electrocution, to illustrate incompetence and thereby indoctrinate newcomers in the lab's 'safety culture'. Although some research communities value risk-taking as brave, Sims argues that the plasma lab workers' stories illustrate their commitment to training novices in compliance, care and safety: 'Those who seem willing to compromise real safety (as opposed to certain institutional safety rules) for the sake of scientific productivity are generally seen as deviant, not heroic' (2005: 341). The stories are intended to scare listeners into respecting the equipment and its proper use by *not* behaving like the unsafe deviants who star in

the stories, echoing disaster stories' theme of 'don't do this'.

Stories also convey messages about values and gender roles in science and engineering. Science textbooks report the history of a discipline through brief hagiographies of a few individuals (Kuhn, 1996). Similarly, Traweek (1988) found that physicists tell somewhat apocryphal success stories about individual physicists to inspire students to do better work. She argues that these stories are 'male tales' that promote 'masculine' values and, in her study, were told only by men. For example, these stories present physicists' research as more important than all else (e.g., family) and celebrate 'independence, experience, competition, and individual victories [which] are strongly associated with male socialization in our [American] culture' (Traweek, 1988: 104). Male tales, then, convey a basic history of the community alongside moral values of prioritizing self over others and research over relationships. There were no women physicists in the labs Traweek studied, so it is not known whether they might have told similar stories.

A few studies shed valuable light on engineers' knowledge and community, but without addressing their socialization processes or discourse styles (Forsythe, 2001; Johnson, 2009; Madhavan, 2015; Vincenti, 1990; Vinck, 2003). One notable exception is Bucciarelli's (1994) study of engineers' design processes, which include 'story-making' as a crucial component of imagining and assessing possible designs. These stories are sociotechnical scenarios that engineers 'fabricate' for each other as a kind of thought experiment, to assess potential outcomes of imagined designs and thereby inform engineers' collective decisions about which designs to pursue (Bucciarelli, 1994). Bucciarelli points out that engineers' norms of language and worldview shape these stories, but doesn't discuss how engineers learn these norms or how to interpret or tell such stories.

Stories about failure

Expert researchers tell stories to novices to normalize failure and create productive spaces for problem-solving (e.g., Bhattacharyya and Bodner, 2014; Campbell, 2003; Delamont et al., 2000; Delamont and Atkinson, 2001; Hackett, 2005; Walford, 1981). Data from these studies include stories about failure, but not stories about how to avoid failure (i.e., disaster stories). For example, one biologist said of a graduate student's project, 'We were mapping a gene that seemed to be important for something, and it turned out we couldn't map it. … It was obvious

there was a problem there, so it got dropped', meaning that they gave up on the project (quoted in Hackett, 2005: 790). Instead of being specifically didactic about how to do research, this story, and others like it, communicate the general message that failure is required to identify successful research questions and methods. Failure, then, is portrayed as a valuable component of future success. Delamont et al. (2000) describe the failure to achieve desirable experimental results as an integral part of graduate students' acquisition of maturity, independence, and identity as researchers. Their interview data of graduate students and supervisors contain detailed stories of failure and problem-solving told as part of a grand narrative of eventual research success. As an example of a success story, a graduate student said, 'For the first fifteen months, nothing worked. I didn't panic too much, although it is very disheartening, as everyone gives you a lot of reassurance and support. It always comes together in the end. That's what everybody tells you. And it did!' (Delamont and Atkinson, 2001: 92). This story about the student's own socialization emphasizes the importance of lab members' empathy, alongside their vague advice to keep trying.

In my interviews, and apparently in other STS researchers' interviews, research participants typically do not tell disaster stories. Perhaps this is because interviews are not didactic situations. Observing lab work may be the only way to witness this discourse style, as Delamont and Atkinson (2001: 98) did for one disaster story. In a meeting, graduate student Dave explains that his cell cultures have an infection. His advisor and a postdoctoral researcher list possible explanations, such as how contamination is encouraged by opening lids, the time of year, temperature, and the cells' species. These factors are suggested to help Dave troubleshoot; they are not personal stories. However, the last line of the published excerpt is from postdoc Christine: 'I used to get mould problems' (Delamont and Atkinson, 2001: 98). Christine's story is brief and lacks specific information about her problem, though it's possible that the story was cut off in the published account. Note that Christine is a woman speaking to least two men (based on the pseudonyms' gender), perhaps suggesting that disaster stories accomplish social functions typically attributed to women. Fletcher (2001) calls these social functions 'relational practice', such as the invaluable yet unrecognized everyday tasks that women engineers do to build relationships and enable effective interactions at work. Tannen (1990) argues that women often exchange stories of failures without offering advice, a discourse style she calls 'troubles talk'. 'Troubles talk is intended to reinforce rapport by sending the metamessage "We're the

same; you're not alone"' (Tannen, 1990: 53). Christine may be telling Dave that she has shared his problem to reassure him, rather than to suggest a solution.

Success and disaster stories both normalize failure and encourage students to overcome it. However, they are different in important ways. Success stories include implicit or explicit assumptions of eventual success and are common in research communities (Delamont and Atkinson, 2001: 98; Traweek, 1988). And whereas success stories tend to be impersonal, stories of failure are often personal. There is some evidence that learning by reading 'error stories', i.e., written case studies about poor decisions, is more effective than learning by reading 'errorless stories' of success (Joung et al., 2006). Reading a generic error story must be less meaningful than hearing an error story told by the person who made the error. This assumption is borne out by my ethnographic observations.

Kate and her students tell both success and disaster stories. However, the culture of Kate's lab is unusual because she and her students share personal experiences of failure without a happy ending, pride, or hope that listeners can help. Many of the social values and relational practices conveyed by disaster stories are missing or weak in success stories' reassurances that failure is part of triumph. These two kinds of stories – of success and disaster – shed light on the typical values and norms that engineers impart to future engineers, such as commitment and individual responsibility, alongside previously undocumented values, such as humility and collective (and vicarious) learning. Specifically, the reputational damage that a teller risks by telling a disaster story, much like making a self-deprecatory joke, encourages trust and empathy (Holmes, 2000: 170), as opposed to the potentially patronizing tone of delivering vague, impersonal advice or heroic success stories. The message of success stories is 'learn from your mistakes', as compared with disaster stories' invitation to 'learn from *my* mistakes'. Furthermore, if the graduate students I studied believed that they needed to compete with each other for success, as Traweek notes about young physicists (1988), then it would not be in their interest to share information gained at the cost of their time and effort lost to failed attempts. This sense of interdependent success instead matches the so-called 'feminine' values of collaboration, mutual support, and nurturing (Traweek, 1988: 104). Fletcher (2001) found similar appreciation for (masculine) individual achievement and autonomy and devaluation of (feminine) teamwork and relational skills expressed in the discourse style of men in an engineering company. Other gendered norms in ways of talking about engineering include

labeling technical or 'hard' tasks as masculine and social or 'soft' tasks as feminine (Dunbar-Hester, 2008; Faulkner, 2000, 2011; Hatmaker, 2013; Seron et al., 2015).

This study provides insight into how constructing and sharing knowledge through personal stories reflects and shapes the culture of research communities and, accordingly, the personal and professional development of future practitioners. I argue that inviting vicarious learning by telling disaster stories, as opposed to success stories, encourages a collective and collaborative workplace culture.

Methods

To observe socialization in action, I conducted an ethnography of two engineering research communities during two academic years (2016-2018), plus two additional communities for one academic year (2017-2018)(Wylie, 2018, forthcoming; Wylie and Gorman, 2018). The four groups are in the engineering college of a medium-sized US public research university. I chose these groups because undergraduates regularly work in them, they belong to different fields of engineering, they have different levels of representation of minority racial, ethnic and gender groups, and their PIs welcomed my study. All four groups tell personal and generic stories about failure, generally in an encouraging sense that failure is an obstacle on the path to success or even as an indicator that one's attempts are appropriately innovative and bravely risky. Only one group also told negative, self-deprecating stories about personal experiences of failure without a promise of eventual success. As a result, this paper only analyzes data from that group, led by tenured professor Kate, to assess this unusual discourse style and its effects on the group's members and research.

Kate and her students study the properties of engineered materials, including metals, ceramics, and glass. During my study, the research group included Kate, one postdoc, seven to nine graduate students, and three to five undergraduates (see Table 1). The majority of lab members were women. One to two lab members were minorities (meaning from racial or ethnic groups underrepresented in engineering in the United States) (c.f. National Center for Science and Engineering Statistics, 2017; Roy, 2018). Three undergraduates had worked in the group for at least one term before I started my study. One undergraduate and two graduate students graduated in 2017, and three new undergraduates joined the group that fall.

Table 1: Demographics of Kate's lab in 2016-2018

	Group members	**Under-graduates**	**Women**	**Underrepresented minorities**
2016-2017	14	3	9	2
2017-2018	14	5	8	1

I attended meetings and shadowed each undergraduate several times in the lab. My goal was to observe moments of learning. Disaster stories emerged as a striking medium of knowledge transfer and socialization. I witnessed the telling of only 15-20 disaster stories, which suggests that they are not a common occurrence. However, they are usually told during lab work, which takes place in the evenings, in the middle of the night, and on weekends; times during which I was often unavailable for participant-observation. It's likely that disaster stories are told more frequently than my data represent. In addition to participant-observation, I interviewed the students and Kate about their experiences of working together. Interviews were audio-recorded and transcribed. Three undergraduate research assistants and I collectively coded the transcripts and my written fieldnotes. We used grounded theory and inductive analysis (Creswell, 2007) to identify a variety of themes relevant to socialization, of which one was disaster stories.

These qualitative methods fill a gap in existing research about the socialization of undergraduate students who work in research communities. Most studies of socialization in science and engineering focus on graduate students (e.g., Campbell, 2003; Delamont et al., 2000; Hackett, 2005; Walford, 1981) or pedagogy (e.g., Kaiser, 2005). Studies of undergraduate lab workers primarily use quantitative surveys to measure undergraduates' and faculty's experiences and to look for correlations with students' academic success and career choices, often long after students worked in labs (e.g., Bauer and Bennett, 2003; Lopatto, 2004; Russell et al., 2007; Zydney et al., 2002). In comparison, interviews create space for lab workers to suggest their own causal explanations and allow for the collection of qualitative versions of students' and mentors' experiences (Dolan and Johnson, 2010; Hunter et al., 2006; Seymour et al., 2004). Surprisingly, there are no prior participant-observation studies of undergraduates in labs. In my study, participant-observation offers a direct view of how undergraduates, as the most novice learners in academic labs, interact with other researchers. These interactions reflect how engineers train

novices, how novices interpret this training, how they acquire tacit knowledge of engineering practices and behaviors, and how they develop a sense of belonging in the lab community and the field of engineering. Undergraduates, then, are an informative indicator of socialization more broadly.

Disaster stories in context

In Kate's lab, failure is shared openly, but only sometimes does it imply eventual success. This section analyzes disaster stories by the three categories of research practice that they address: decrying poor skill, defining proper and improper techniques, or discussing career paths. Surprisingly, I never heard anyone tell a disaster story about theory, in the sense of a failed hypothesis or disappointing negative results. Group members certainly talk about theories and results, but not in the form of disaster stories. It's possible that they don't consider theory failure a result of personal failure, unlike the errors of skill, technique, and career decisions. Why they don't apply this genre to epistemic failures deserves further study.

Disaster stories appear most often when graduate students are teaching undergraduates how to conduct specific lab tasks. In effect, the storyteller is giving advice about how best to proceed, based on their own experience. It is up to the learner to understand and act on this advice, to learn vicariously through the more experienced engineer's mistakes. Disaster stories are not as direct as instructions; often they don't define a 'correct' way to do a task, but rather a wrong way that the teller has tried and suggests that the learner avoid. There are therefore many unspoken messages in a disaster story, which a novice must learn to understand and embody to succeed in the lab community.

Instead of giving direct instructions, the use of storytelling in Kate's lab has the effect of reducing hierarchy and offering a welcoming sense of solidarity by implying that the teller and the listener are in a shared endeavor. Self-deprecation can be a way to protect oneself from the high expectations of others, or to obscure one's successes in the case of imposter syndrome (De Vries, 2005: 4). However, rather than a form of self-defense, Kate and her students use disaster stories to share information in a humble and generous manner. After all, they tell disaster stories *down* the hierarchical ladder to lower-status coworkers. A PI has no need to protect herself from a student's assessment of her success, for example. Kate tells these stories from a position of power that is obvious to her listening students, as do graduate students when they tell stories to

undergraduates. But the storytellers never mention their higher status explicitly. Instead, in telling disaster stories, Kate admits that she makes mistakes and that she doesn't know all the answers. She offers her own experience for students to consider and learn from. The group's practice of vicarious learning through telling disaster stories stems at least partially from Kate's use of this discourse style.

Skill

Disaster stories about lab skill, or, more accurately, about its absence, are the most straightforward examples of humility and implicit instructions of what not to do. For example, in a meeting, graduate student Hannah mentioned that she had dropped one experiment's material samples before they were analyzed, breaking them and making them useless. The room filled with sympathetic cries of 'Aww!' No one suggested any silver lining – practical or epistemic – to Hannah's misfortune. Instead, the lab members commiserated, no doubt having experienced similar disasters themselves. The unspoken understanding was that Hannah would redo the experiment, but that was not considered relevant in this moment of grieving for Hannah's wasted time and effort. Interestingly, Hannah told this story to an audience of her advisor, her peers, and a few undergraduates. She was not instructing anyone in lab practices, although one can imagine a novice nonetheless making a mental note not to drop samples as a result of Hannah's story. Furthermore, no one questioned Hannah's overall research competence and skill based on this story. It was treated as a stand-alone disaster rather than an indicator of Hannah's ability or of the success of her research question or methods. Because this story didn't harm her reputation, solicit advice from others, or offer instruction, perhaps Hannah told it primarily to request sympathy or as a form of comic relief.

Disaster stories about lapses of skill tend to be told and interpreted as instances of tough luck, rather than as moments of identity definition. For example, when I asked graduate student Kenny and undergraduate Gretchen whether they felt safe working with the lab's equipment, Kenny responded with a disaster story. He said that when working in another lab he'd accidentally dropped a hot material sample on the floor, starting a short-lived fire. 'That's something you're embarrassed about and then you get over', he concluded calmly, while Gretchen and I exclaimed in shock at the idea of causing a fire. This could be understood as a success story, in that Kenny's presence in Kate's lab implicitly demonstrates that he had

managed to continue his research career. However, he gave no indication that this fire was somehow educational, inspiring, or otherwise productive. He merely acknowledged the 'embarrassing' existence of a mistake and recommended an appropriate response, i.e., to 'get over' it, rather than find a silver lining to recount this event as a success story. His message that sometimes even the skills of very skillful people fail could sound forgiving and supportive to a novice like Gretchen. The story offers advice for how Gretchen should react to the failures she is bound to encounter as a researcher, thereby sparing her the need to discover this approach on her own.

In another example of a disaster story about skill, graduate student Joe credited undergraduate Liam with preventing a disaster. Joe was teaching Liam how to use a mounted rotary saw to cross-section metal samples with holes punched at one end. Joe narrated how to place each sample in a vise to hold it against the sawblade, emphasizing the importance of cutting it in the correct orientation. He commented calmly, 'Fifty percent of the time I end up cutting the side with the holes, which doesn't work. [laughs] It's the opposite side!' This narrative reinforces Joe's practical warning to orient the sample correctly, by admitting that he himself often does it wrong and it therefore deserves extra care. Joe added, 'Now that I'm showing you I'm thinking more about what I'm doing, so I'm not going to screw it up this time.' Thus, the common cause of this particular disaster is not inadequate skill or incorrect technique, but rather a lapse in attention. Joe notices aloud that he is more careful with an audience, which may serve to invite Liam into the research process and acknowledge his participation, even though Liam is only watching. Thus, stories about disasters caused by failed skill tend to portray skill as largely stable but subject to variance in the researcher's momentary luck and attention.

Methods and techniques

Graduate students in Kate's group most often tell disaster stories to guide undergraduates' performance of lab techniques, indirectly explaining how to do tasks by demonstrating bad approaches. Disaster stories can help clarify instructions and make warnings memorable, but alone they are insufficient to teach techniques. Their social function, then, may be just as important as their instructional function. I first noticed that graduate students told self-deprecating stories about mistakes and bad outcomes to undergraduates because such stories sounded like jarring confessions of the teller's incompetence. Indeed, disaster stories empower

listeners by granting them access to potentially damaging stories about higher-status workers. More importantly, the admission of incompetence conveys that the story is a generous, selfless sharing of hard-won information. After all, workers' willingness to take responsibility for their mistakes helps build trust and collaboration in a workplace (Patriotta, 2003: 367). I suggest that the self-deprecation of recounting personal mistakes deemphasizes the hierarchical gap between teller and listener. Being entrusted with negative stories may help the listener feel like an accepted member of the community.

In one story told to reinforce proper technical procedure, graduate student Kenny was helping undergraduate Gretchen set up an experiment. First they needed to replace part of the equipment by cutting a thin glass tube to a certain length (which Gretchen later threaded with wire, as already recounted). Because Gretchen had not cut a glass tube before, Kenny narrated how to place the tube into a vise while Gretchen carried out his instructions. Kenny watched her actions and occasionally corrected them, either verbally or by physical demonstration. He was calm and friendly rather than demanding or critical, and egalitarian rather than dictatorial. When it was time to orient the glass-cutting apparatus, Kenny said, 'I always mess up doing this.' He then demonstrated the *wrong* way – the trap he apparently falls into – and then a better way, as Gretchen watched. He thereby showed Gretchen a pitfall so that she could avoid it, which helps define good technique. He shared his hard-learned lesson to save her the trouble of learning it from her own experience by instead learning it vicariously from his experience. Crucially, he said that he can and does 'mess up', admitting his own humanity and ongoing learning and lessening the power differential between Gretchen and him. A few minutes later, he similarly warned Gretchen, 'Never hand-cut, it'll break it [the tube]. I've done that many times.' He shook his head and rolled his eyes in embarrassment and disgust at his apparently oft-repeated misdeed. Kenny could have pulled rank by simply ordering Gretchen to 'never' hand-cut tubes, but instead he offered his own experience of failure as evidence of the soundness of his advice. His story also implicitly instructed Gretchen how to learn from personal experience, i.e., that he knew not to hand-cut glass tubes because he had tried it 'many times' and failed.

One might interpret this example as a *success* story, in that Kenny did indeed figure out techniques to cut tubes without breaking them thanks to his failed attempts. However, Kenny frames the story as one of failure, by highlighting his own misadventures with bad techniques, and does not articulate a happy ending. One could imagine this story being told in the form of 'I

learned that this technique works best', which is a more generic and less evocative narrative than Kenny's dramatically shattered glass tubes and his theatrical performance of frustration as part of the storytelling. Perhaps the emphasis on bad outcomes is more engaging for a learner, improving their comprehension and retention of information relayed in disaster-story format. Gretchen did, after all, cut the tube without breaking it on her first try. Framing a story around failure is a different approach from framing a story around *overcoming* failure, and has different implications for the social values that the listeners learn.

Humor, as in Kenny's self-deprecating eye-roll, is often used as a way to define social groups, such as making jokes that an outsider group will not understand (Tracy et al., 2006: 285). In this case, disaster stories demonstrate a form of *inclusive* humor; Kenny acknowledges Gretchen as a member of the lab by telling her bad ways to work. Also, he doesn't tell her why it's bad to break tubes; he assumes that she already knows that. Rather than bossing the undergraduate around, the graduate student commiserates, shares stories, and actively tries to help her succeed. Telling disaster stories is a way of enacting the community's values of collaboration and mutual learning, by leveling the playing field through assertions of the higher-status worker's occasional incompetence. This is not the competitive, self-centered culture that Traweek (1988) witnessed among young physicists.

Likewise, after undergraduate Frank made a string of mistakes while doing a technique, graduate student Alison admitted her own error as a way to reassure him. They were setting up an experiment that Frank had run a few times before, and Alison was quizzing him throughout the process to assess and cement his knowledge. One exchange went approximately like this:

Alison: What do you want to do next?

Frank: [uncertain] Start the gas flow?

[Alison agrees and shows him which levers to flip.]

Alison: [hinting] Anything you want to do with the furnace?

[Frank shrugs, indicating that he doesn't know.]

Alison: Something you don't want to heat up?

Frank: [uncertain] Shield?

[Alison agrees, and Frank positions a small metal shield around a glass tube on the apparatus. Alison immediately adjusts the shield's position.]

Alison: You don't want the shield to touch the glass.

The pattern of Alison's guiding questions and Frank's question-intoned answers or lack of answers went on for several minutes as they assembled the experiment. Frank often performed a task, such as moving the shield, that Alison would then redo. This feedback process can be stressful for a learner. Frank respectfully carried out Alison's instructions, but with few words and minimal eye contact. He may have felt frustrated or embarrassed by his mistakes. Alison was uncomfortable too, fidgeting as she waited for Frank's answers and for him to fix aspects of the set-up. She didn't seem to enjoy the role of quality-controller. This mutual unease with the existing hierarchy may have inspired her to lighten the mood and remind Frank that she is learning too. As Frank worked on a task she'd assigned him, Alison said she would weigh part of an experiment she'd done earlier that day. 'I never did that', she said guiltily, implying that she should have weighed it immediately. She was indicating to Frank that this is not ideal practice, while also leveling their hierarchical difference by pointing out her own protocol misstep. She may be demonstrating Tannen's 'troubles talk' (1990), i.e., building rapport by admitting to experiencing similar frustrations as Frank. For his part, Frank likely knew enough about the group's practices and discourse to understand that Alison was confessing to making a mistake. No disaster resulted from her delayed weighing, but her admission of not following ideal lab techniques nonetheless implied that she, like Frank, is learning and that imperfect work happens.

It does not benefit Alison to admit this error, but it informs Frank about the (im)proper technique and invites him to feel at home in the lab despite making mistakes, because Alison makes mistakes too. In Goffman's (1967: 9) term, a teller of disaster stories can thereby 'give face' to lower-status workers, meaning that the teller protects or bolsters the listener's reputation and sense of self, even if the listener is underperforming. By reassuring Frank that she and he are not so different after all, Alison may also be extending support for a fellow member of an underrepresented group in engineering, as Frank was one of only two people of color in the lab that year. Alison, as a woman in engineering, knows what it's like to be a minority. Women and people of color are minorities in most engineering communities in the United States (National Center for Science and Engineering Statistics, 2017; Roy, 2018), and encouraging these groups' sense of belonging is a significant factor for their retention in engineering degrees and careers (Gentile et al., 2017; Malcom and Feder, 2016). Everyday interactions like this one shape the learning, reputation, and sense of belonging of all community members.

Disaster stories can also convey the *necessity* of not knowing what to do, not just its commonality. When graduate student Sam gave a talk to the group about the ongoing early stages of his research, he explained his experimental setup as an experiment in itself: 'That's how it goes at the start, when there's no data. You just gotta guess' the appropriate parameters and procedures for new experiments. He then portrayed his forced guesses as failures, by arguing that his results had so far shown that his methodological choices were ill-suited to his goals. He lamented, 'I've done a lot of experiments and gotten a lot of crappy data. But that's how it goes.' The implication is that his guesses and resulting 'crappy data' were required steps on the path to developing a successful experimental procedure. He seems to assume that he will reach this sought-after goal eventually, based on his repeated Kurt Vonnegut-like 'that's how it goes' comment about the failure-laden nature of research in general. However, this hope is heavily obscured by his narrative's focus on wasted time and effort, without mention of the insights he must have been gaining even from the failed attempts. Of course, learning what doesn't work can be an important component of learning what does work, but Sam did not choose to tell his story as a path to success. Also, Sam's resigned attitude toward prolonged failure resembles Kenny's view that researchers must 'get over' mistakes. Taken together, these students' stories suggest that it doesn't matter whether failures are self-induced or unavoidable; they should inspire the same persistent continuation of work. Portraying failure as a painful loss of an investment of work communicates the importance of effort and not giving up in research.

In addition to these subtle functions of communicating appropriate behavior and mindset, most disaster stories are intended to directly influence listeners' actions. Kate tells few technique-related disaster stories, perhaps because she rarely does bench work, but I heard her tell one to undergraduate Frank as an attempt to change his decisions about his research. She warned him that his planned experiments contained too many variables, a danger because 'you don't want it to be in the Journal of Irreproducible Results!' The title made Frank laugh. Kate then illustrated her advice with a disaster story, by admitting that another researcher had tried and failed to reproduce the results of Kate's master's thesis. This news had upset Kate at the time, and she claimed defensively to Frank that she didn't know why the researcher had not succeeded because '*I* can repeat it!' Clearly this incident had not impeded Kate's overall research career, but it bothered her nonetheless that other researchers might think that she hadn't performed replicable experiments. This story was Kate's attempt to protect Frank from such an

accusation, as well as to teach him about the community's values and definitions of good research design. This conversation, perhaps thanks to the disaster story, succeeded in convincing Frank to redesign his experiments.

Career paths

Kate and her students sometimes tell disaster stories to offer vicarious learning on topics beyond lab practices, suggesting that they find this discourse style effective for communicating more general information about how to be an engineer. Kate often shares one such story in response to students' questions about whether they should choose careers in academia or industry. She explains that working as an engineer in industry taught her 'really fast' that she wanted to do a PhD. She describes her industrial work as repetitive, time-consuming, and not creative. 'I wanted to think more than this', she told one undergraduate. She then corrected herself: 'About deeper things than this. I *was* thinking' but not as 'deeply' or theoretically as she wanted to and as she believed academics did. The story does not explicitly end with her happily becoming an academic; instead, it frames her industry job as a powerful experiment that drove her away into another career. Nonetheless, the listeners know that Kate became a tenured professor. Why doesn't Kate finish this story with the flourish of career success, thus turning it into Traweek's (1988) 'male tale' of overcoming hardship? Kate explains to various audiences of undergraduate and graduate students that the moral of this story is not to criticize industrial work (or, implicitly, celebrate academic work), but rather to encourage the students to try a variety of paths, such as different internships, classes, and research projects, to help them choose the best one for them. Working in industry was not a disaster for her, per se, but Kate recounts her career path in the form of a disaster story. However, this story lacks the 'don't do what I did' moral of disaster stories, arguing instead that students *should* try different careers as Kate did.

One graduate student, Laurie, imitated Kate's story by telling undergraduates Jessie and Frank about the difficulties she'd experienced by going to graduate school later in life. It is possible that Laurie learned this discourse style from Kate during their years together as student and advisor. But, unlike Kate, Laurie framed her advice as a disaster story in the form of 'don't do what I did'. The story had a profound impact on the students, who both independently recounted it to me in interviews when I asked about their future career plans. Jessie explained,

> With [Laurie's] 401K [retirement savings plan] and stuff like that, stuff got messy, going back to school. And then also she has a daughter now, so that is tough. … It's just a hard time in your life to go back to school. And especially after making money to drop back down to being a student is – I guess a lot of people don't end up going back [to school].

Jessie told me the personal, narrative elements of Laurie's experience and the generalized conclusions that she (or perhaps Laurie) drew from it. In contrast, Frank focused on Laurie's advice:

> Frank: I asked her, like, should I take the time off? And she was like, 'No, do your PhD now [laughs] before you get a family and kids.'
>
> Caitlin: She counseled you against what she had done?
>
> Frank: [laughs] Yeah, she was telling me, like, 'Do it, do it, just do it now while you're young and dumb [laughs] or just have the time for it.'

Either implicitly or explicitly, Laurie advised the undergraduates to go to graduate school immediately. The undergraduates valued hearing Laurie's story, and it's possible that they trusted her more as a coworker because she shared her personal experience in the hope of helping them make better choices than she felt like she had.

Laurie's career-path story pushes different advice from Kate's: go to graduate school now because it will be harder later vs. try lots of paths to find what suits you. However, both stories share the same structure: the teller's own decision-making and its difficult results, framed as evidence to inform the listeners' decision-making. Both stories arguably end in success, in that at the time the tellers were a senior graduate student approaching graduation (Laurie) and a PI (Kate), but both stories focus on the challenges along the way rather than on the light at the end of the tunnel. Another shared moral of these career stories is that the path will not be easy or linear.

Vicarious learning as communal

The portability of the disaster story discourse style is evident from its practice by Kate's lab members of all hierarchical levels and genders. It appears to be a part of the group's culture. Learning through others' experiences requires community. Therein lies the power of storytelling: it encourages social interaction and relationship-building, and helps align how community members think. Accordingly, novices must learn from storytelling as well as 'learn *to* talk as a

key to legitimate peripheral participation' in a community of practice (Lave and Wenger, 1991: 109, original emphasis). Because disaster stories are told didactically, undergraduates, as the least experienced researchers, are listeners far more often than tellers. There were only two occurrences in which I heard an undergraduate tell a proto-disaster story, which imitated the discourse style, albeit imperfectly. In a sense, the students were practicing talking like their mentors.

Both stories fit the model that the students had heard many times: teaching someone how to do a technique by narrating what not to do, based on experience. In one case, undergraduate Jessie had been regularly melting a material for her experiments for over six months and Kate had asked her to help Erin, a new graduate student, learn this task. Thus, unusually, an undergraduate played the role of an expert relative to a graduate student as a novice. Jessie reported to Kate and me that 'I met with Erin earlier this week about how I melt down my [samples]. … I was just telling her what I know, like "this thing happened once and I've been trying to avoid it happening again."' Jessie didn't portray her interaction with Erin as a delivery of authoritative instructions or step-by-step protocols. Instead, she gave a narrative about things that have gone wrong and her later attempts to avoid them. Her story, at least as she recounted it to us, lacks true disaster stories' specificity about what went wrong, but it captures the genre's structure and self-deprecatory spirit. Jessie further discounted her own knowledge and contribution to Erin's learning by saying, with a shrug, 'I was just telling her what I know.' This may suggest a low level of confidence in herself as a researcher, perhaps because she is an undergraduate and also one of only two people of color in the lab. However, Jessie's humility and willingness to share her personal experiences of failure also reflect her socialization into this community. In her experience, telling disaster stories is a normal mode of delivering technical advice. She is now carrying out that work herself, no longer only receiving it from other storytellers.

In the second undergraduate-told example, undergraduate Gretchen narrated an event she had witnessed in the form of a disaster story. She and I were alone in the lab, and she fell uncharacteristically silent as she delicately adjusted a sample by angling a long metal rod into a blazing hot furnace. When she finished, she explained that she had given the task all her attention because the previous week, while she was working with graduate student Sam, he had adjusted the sample and then accidentally touched the metal rod to an interior edge of the furnace, melting

the rod in an instant. He had had to stop the experiment, clean the furnace, replace some components, and run the furnace empty for a few days to burn out impurities, wasting his time and delaying his research. Gretchen used Sam's disaster to explain her own meticulous work to me, framing her careful focus as a response to her fear of doing what Sam had done. Gretchen wasn't *told* this disaster story; instead, she applied the genre to explain what she had witnessed of Sam's experience of momentarily failed skill. Gretchen knew more about the task than I did, so she was an expert to me as a learner, matching the pattern of disaster storytelling. However, Gretchen was not warning me against touching the rod to the furnace. So her story lacks the pedagogical aspect of vicarious knowledge-sharing. Instead, she adopted the disaster story framework to share Sam's mistake with me, as a way to explain her own lab practices (which she knew I was watching and interested in) and perhaps also as intriguing gossip. By imitating the style of disaster stories, Gretchen and Jessie are participating in the dynamic process of constructing their community, by enacting its values of learning, knowledge-sharing and modesty. By matching the genre imperfectly, these undergraduates demonstrate their incomplete and ongoing learning towards becoming socialized contributors to the group's work, knowledge, and social structure.

One might worry that disaster stories serve a desensitizing function, by normalizing failure to the point that learners become inured to it. This desensitization could perpetuate true engineering disasters, such as bridge collapses (e.g., the Tacoma Narrows bridge in Washington in 1940, a pedestrian bridge at Florida International University in 2018, a highway bridge in Genoa, Italy, in 2018), the explosions of spacecraft (e.g., the *Challenger*, the *Columbia*, the Mars Climate Orbiter), or shockingly unethical decisions (e.g., knowingly lax safety precautions in the American chemical plant in Bhopal, India, or the corporate culture of silence that enabled Volkswagen to cheat on emissions tests). Disaster is a narrative that undergirds engineering and engineering education (e.g., Petroski, 2001; Pfatteicher, 2002). Perhaps this approach can normalize failure, thereby making it seem somewhat acceptable and expected to engineers. However, disaster stories, like other disaster narratives in engineering, are told to avert disaster pedagogically, by inspiring learners to follow good practices (or, at least, to not follow bad ones). They do not celebrate failure as admirable, even at the small scale of dropping samples or breaking tubes. Also, listeners never show nonchalance at disaster stories; they typically express shock and empathy. Furthermore, tellers almost always included an emotional response in their

storytelling, such as frustration or disgust. These are not intended to be desensitizing stories and could even serve as the opposite, by portraying the emotional costs of failure to novice engineers. When these bad experiences happen to learners' own trusted mentors, their pedagogical and socializing power is arguably all the stronger.

These examples help define what disaster stories are and how they construct and communicate the culture of a research workplace. These stories impart valuable technical and social knowledge to learners, while reducing hierarchy and building trusting relationships. The stories are told didactically, not just for comic effect, self-deprecation, or as friendly chat. They communicate concrete information about what happens if you do a procedure in a certain way (e.g., what causes disasters) and implicit information about how engineers should act and think (e.g., 'get over' mistakes, try a variety of possible careers). Specifically, disaster stories contain a 'don't do what I did' message, built into a narrative of an unflattering experience of failure. The message is framed as advice and personal storytelling rather than as facts, instructions or commands, which are common in classrooms. In my observations, students listened closely to these stories and did not reciprocate with stories of their own mistakes. This omission of exchange reflects the disaster story as a pedagogical tool, distinct from the conversation style of casual story-swapping or 'troubles talk' (Tannen, 1990). This mode of storytelling also implies that this community treats undergraduates as coworkers and co-learners who are capable of making their own decisions (see Wylie, forthcoming).

Conclusion: Vicarious learning to build learning-focused research communities

After the first year of my study, I joined Kate's group for their traditional end-of-semester celebration lunch. During the meal, a graduate student asked me about my findings, so I told the group about my favorite emerging theme: how they tell each other stories about failure. They laughed and nodded. They were surprised, however, that neither the other group in my study nor the research participants of other scholars' studies tell disaster stories; for them, telling such stories is normal. Kate asked me to present my findings to the group that summer. After my presentation and a lively discussion, the students, with giggles and conspiratorial looks, said they wanted to show me something in the lab. Intrigued, I followed the whole group to the lab's shelves, where graduate student Sam and undergraduate Gretchen proudly pointed at a new sign

they had installed: ‘DISASTER STORY SHELF’ (figure 1). Sam said to me with mock reverence, ‘This is your legacy in the lab.’ Then he told the origin stories of the bizarre objects on the newly labeled shelf, including a melted, mangled piece of metal and two large Pyrex beakers, one missing its bottom and the other with shatter lines running through it. Each artifact was labeled with a date, the names of the students who created it, and a phrase describing its formation, such as, ‘Heat up cold water too fast on hot plate’ for one broken beaker. The lab had turned the display of disaster stories into a medium of instruction and relationship-building. A few months later, I asked Gretchen whether students were still adding objects to the shelf, and she laughed and said, ‘I love that shelf. Even if you mess something up, you can put it on the shelf! It’s a silver lining.’ By naming disaster stories, I had changed the group members’ awareness of their own discourse. They embraced the public recognition of failure as a source of empathy and comedy. In the second year of my study, the group continued to tell each other disaster stories in the same structure as I’d documented in the first year.

Disaster stories are a mechanism for vicarious learning and a crucial medium of socialization. Vicarious learning benefits the learner as well as the lab community, which needs the learner’s work and invests effort in training and in fixing mistakes. Experienced members share their mistakes to prevent learners from replicating them; this practice has the potential to improve the group’s overall work. But pursuing efficiency only partly explains the value of vicarious learning. It leaves out the crucial contributions that disaster storytelling makes to novices’ socialization and community-building. Learners acquire tacit knowledge as part of their immersion in the community of practice of engineering research, which includes listening to stories. After all, to learn an intended lesson from a story, the learner has to interpret it as the teller did, requiring at least partial comprehension of the community’s social norms. This is how learning from immersion happens. In addition, learning from disaster stories relies on mutual trust between teller and listener. When a teller entrusts a listener with a story of his or her own failure, it inspires trust *from* the listener in exchange for this confidence. I never heard a teller say, ‘Don’t tell anyone’; nonetheless, listeners rarely retell others’ disaster stories, suggesting that the telling implies a trust that the listener then reciprocates with respectful secrecy. Disaster stories don’t become the widely-told legends common in workplace communities (e.g., Trice, 1993). Telling them creates a sense of relationship, because the listener learns more about the teller and the teller receives the listener’s attention. Furthermore, personal stories are likely to be

engaging and memorable, improving the chances that listeners think about them, remember them, and learn from them.

The values of generous knowledge-sharing, mutual learning, and relational practices that disaster stories express are an important divergence from typical research stories that celebrate individual success and competition, such as Kuhn's (1996) textbooks' hagiographies, Traweek's (1988) male tales, and Hu and coauthors' (2012) war stories. It's possible that this self-deprecating, inclusive discourse style common in Kate's lab originates with how Kate's identity and reception as a woman shape her worldview, including how she thinks about her research group. Kate's experience as a woman engineer may also explain why her lab has more women students than most engineering communities. More research is needed to investigate how storytelling reflects tellers' identities and influences communities' recruitment and retention of students from underrepresented groups in science and engineering.

Vicarious learning has great educational and epistemic power, though it cannot function as the sole medium of learning. Learning also has to happen through direct experience. In particular, embodied tacit knowledge, such as how to handle glass tubes without breaking them, requires touch and practice and, arguably, failure. After all, it is valuable practice to apply the research skills of question formation, experimental design, and data analysis to everyday situations, such as assembling equipment and preparing samples, as well as to bigger-picture research tasks, such as designing projects and drawing conclusions. While it is important for novices to learn lab skills and research protocols, they must also learn to act like and identify as a researcher to be successful, a process which stories certainly inform and for which practical knowledge alone is insufficient. Lave and Wenger (1991: 92) argue that 'the issue of conferring legitimacy is more important than the issue of providing teaching'. Thus, social acceptance and a sense of belonging in a community are crucial starting points for learning that community's skill and knowledge. Disaster stories and their associated context of trust, learning and collaboration reflect a lab culture that is welcoming to novices and supportive of all members as continuous learners. Most scientists and engineers already teach their students about failure; basing these lessons on personal experiences of disasters can help create a culture that celebrates learning together while making knowledge.

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Figure 1: Broken equipment on display to document the stories of students' lab disasters.