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# Elementary Teachers' Reflections on Design Failures and Use of Fail Words after Teaching Engineering for Two Years

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**Abstract**

This mixed-methods study examines how teachers who have taught one or two units of the Engineering is Elementary (EiE) curriculum for two years reported on: students' responses to design failure; the ways in which they, the teachers, supported these students and used fail words (e.g. fail, failure); and the teachers' broad perspectives and messages to students about failure. In addition, the study explores how strategies, perspectives, messages, and fail word use may change after two years of engineering instruction. This study builds on previous work about elementary teachers': perspectives on failure prior to teaching engineering, and responses to and perspectives on failure after teaching EiE unit(s) for one year. Data collected included 74 surveys, containing both quantitative and qualitative items, and ten in-depth, semi-structured interviews. Quantitative data were analyzed via non-parametric methods, and qualitative analysis involved an iterative search for codes and themes. The convergent mixed-methods design enabled comparison across quantitative and qualitative findings. Findings included that the elementary engineering classroom is a complex space in which teams may or may not experience design failure; for those teams that do, they—and, in turn, their teachers—may respond to this experience in a wide range of ways. Also, after two years of teaching engineering, teachers felt more comfortable preparing students for design failure experiences, and responding when design failure occurred. Most also felt more comfortable using fail words, and when they used these words, learned to do so with context and care.

*Keywords:* failure, engineering design process, elementary teachers

The inclusion of engineering design within elementary education, motivated most recently via the *Next Generation Science Standards* (NGSS Lead States, 2013), introduces opportunities for students to not only solve a problem, but to also likely experience design failure in the process. Practicing engineers acknowledge failure as a normal and expected outcome as a part of the iterative nature of designing solutions to problems, although the end goal is that the solution (hereafter, the "design") is *not* intended to fail. Since the introduction of aspects of engineering design in the NGSS, pre-kindergarten through grade 12 (P12) teachers have begun to tackle the dichotomy of failure as: (1) a normal part of engineering, and (2) something to be feared and avoided in most educational settings (Lottero-Perdue & Parry, 2014, this JPEER issue). In the process of teaching engineering to students, the ways that teachers support students whose designs fail and use "fail words" (e.g., fail, failing, failed, failure) offer opportunities to provide a normalized context for failure experiences and fail words in the classroom. This study examines how teachers who have taught one or two units of the Engineering is Elementary (EiE) curriculum for two years reported on: students' responses to design failure; the ways in which they, the teachers, supported these students and used fail words; and the teachers' broad perspectives and messages to students about

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failure. In addition, the study explores how strategies, perspectives, messages, and fail word use may change after two years of engineering instruction.

Although the use of fail words is still an uncomfortable term in education, it is, increasingly, a part of the popular lexicon. This was driven in large part by the STEM (science, technology, engineering, and mathematics) focus brought about by the United States Department of Education and its Race to the Top program, which prioritized STEM teaching and learning (2009). In addition, the "maker" movement has grown rapidly, bringing the idea of iteration and trial and error to the general public (Stewart, 2014). However, failure in these contexts is largely attributed to generic descriptions such as "design," "iteration," or "making mistakes" rather than to engineering. It is in this environment that this study examines how students and teachers respond to engineering design failure and how teachers acclimate to an increased use of and comfort level with fail words.

## Background

Although engineering is now formally included in P12 education owing to the NGSS, teaching engineering remains a complex challenge for teachers at all levels. It is particularly challenging for elementary teachers, many of whom have had little or no learning experiences in engineering (National Academy of Engineering [NAE] and National Research Council [NRC], 2009, 2014).

One important part of teaching engineering is that teachers help students navigate design failure experiences (Cunningham & Carlsen, 2014; Cunningham & Lachapelle, 2014; Moore et al., 2014). Engineering design accounts for the likelihood of failure by its iterative nature; initial attempts to solve a particular problem may fail to meet design criteria or not meet those criteria as well as subsequent designs. "Every successful design," according to Henry Petroski, "is the anticipation and obviation of failure, every new failure—no matter how seemingly benign—presents a further means towards a fuller understanding of how to achieve a fuller success" (2012, p. 45). When end point failure occurs—failure of the final product (e.g., a bridge in use)—analysis of the event is performed to understand heretofore-unknown risks or the impact of unintended usage, or to examine the failure in light of new knowledge or research (Delatte, 2009). Engineers persistently engage in what Petroski calls a "thoughtful reappraisal of even centuries-old failure[s] to yield new lessons from old examples" (2012, p. x).

The introduction of engineering design to P12 education creates the opportunity to address explicitly the idea of failure in classrooms in a new way (Carlson & Sullivan, 2004; Crismond & Adams, 2012). Many in engineering education promote the idea of teaching about failure by having students practice engineering habits of mind (NAE & NRC, 2009). These include: "systems thinking, collaboration, ethical considerations, creativity, communication and optimism" (p. 152). Failure, although not explicitly named, is best exemplified as part of the habit of mind of optimism. Resilient responses to design failure include an optimistic mindset that the problem can indeed be solved or that the failure can be overcome. These responses are representative of a growth mindset, in which students learn from failure and believe that growth is a natural byproduct of failure (Dweck, 2008). Learning to consistently respond to failure via a growth mindset might help students develop grit: resilience over the long haul (Duckworth, Peterson, Matthews, & Kelly, 2007).

Yet what do we know of how teachers—especially elementary teachers—attend to failure, help students navigate failure experiences with resilient responses, or use fail words as they teach engineering? What do we know about how students respond to design failures? Research on P12 teacher and student responses to design failure is limited. Failure is typically addressed as one topic of many others when researchers investigate students and teachers engaged in engineering design experiences. In these studies, we get glimpses of how students generate failed designs, test designs to failure, or conduct failure analysis (i.e., analyzing the causes of a design failure) (Cajas, 2001; Hmelo, Holton, & Kolodner, 2000; Levy, 2013). On occasion, teachers' approaches and responses to student design failure, as well as student responses to design failure, are reported. When discussing design failure, reported student responses range from frustration, quitting or giving up, and analyzing the failure for improvement ideas (Barnett, 2005; Kolodner et al., 2003; Rutland & Barlex, 2008). For teachers, response approaches include teachers discussing their own experiences with failure and striving to create "fail safe" environments for students (Rutland & Barlex, p. 96). The evidence provided in these studies helps to inform on failure as a part of a design process, yet most are limited in scope and/or the study population.

The present study extends and references our earlier work that focuses on upper elementary (grades 3, 4, and 5) teachers, and how they and their students respond to design failure (Lottero-Perdue, 2015; Lottero-Perdue & Parry, 2014, 2015, this JPEER issue). One of these studies examined elementary teachers' perspectives on failure prior to teaching an engineering unit of instruction (Lottero-Perdue & Parry, 2014, this JPEER issue). The study found that while these teachers may regard failure as a learning opportunity, few use fail words in their classrooms. This is simultaneously: unconscious, in that teachers associated fail words with their own negative past experiences and perceptions of failure; and deliberate, in that the teachers expressed concern that the students would identify themselves as failures when their designs failed. The latter is the basis for much debate within the maker movement around the use of fail words in education, with arguments for and against using fail words with students as they engage in design (Clapp, 2015; Martinez, 2013; Martinez & Stager, 2013; Ramirez, 2013). For example, the lead author of *Invent to Learn: Making, Tinkering and Engineering in the Classroom* (Martinez & Stager, 2013)—clearly against using fail words with students—said on a blog post:

> Here's the problem. It's the word "failure." Failure means a VERY specific thing in schools. The big red F is serious. In school, failure is NOT a cheery message to "try, try, again!", it's a dead-end with serious consequences. Using this loaded word to represent mistakes, hurdles, challenges, detours, etc. is confusing and unnecessary. Teachers cannot talk about failure as a challenge, when failure also means judgment—the worst possible judgment. And yes, I do just mean teachers. Specifically, teachers who are grading the work where the "failure" may take place. (Martinez, 2013, para. 5–7).

Referencing this post, Edward Clapp responded that his Agency by Design team is "still questioning this language and thinking hard about the use of the word failure in maker-centered learning" and wondering if the word should be "rebrand[ed] as a pathway to progress" (2015, para. 2).

Two of our previous studies focused on: (1) how students responded to design failures (see Table 1 for summary) and (2) subsequently, how teachers responded to students whose designs fail (Table 2) (Lottero-Perdue, 2015; Lottero-Perdue & Parry, 2015). These studies examine teachers' first year of teaching one or two EiE units to students, and collectively draw from interview, survey, and classroom video data.

Additionally, our previous work has attempted to model responses to design failures in the classroom (Lottero-Perdue, 2015; Lottero-Perdue & Parry, 2015). The simple model shown in Figure 1 depicts three steps after design failure: (1) the students respond to the design failure; (2) the teacher intervenes; and (3) there is a new student response, which may elicit a reconsideration of the design failure, how it can be analyzed, and how it can be improved upon. Caveats with respect to this simple model in our research include that: the design failure itself may not be interpreted correctly, particularly if testing procedures are not followed properly; and there may not need to be a teacher intervention in order for students to engage in failure analysis and improvement, or this intervention may be quite minimal. This former caveat is explored in greater depth in a study by the first author, making the "Failed Design" part of the Figure 1 model more complex; it is also addressed in the "to establish that design failure has occurred …" part of "Specific Interventions" in Table 2 (Lottero-Perdue, 2015).

In summary, in order to have a complete understanding of how engineering can potentially impact elementary teachers and students, the engineering education community needs to understand how teachers and students respond to design failure. Our previous work provides a basis for the range of responses that elementary students have when their designs fail, and provides a range of ways that teachers in their first year of teaching engineering respond to students whose designs fail (Lottero-Perdue, 2015; Lottero-Perdue & Parry, 2015). The present study extends this work for teachers in their second year of teaching engineering to children, providing additional insights into teacher and student responses to failure, as well as into teachers' use of fail words.

Table 1.
Summary of students' responses to design failure (Lottero-Perdue, 2015; Lottero-Perdue & Parry, 2015).

| **Resilient, Productive Actions** | **Non-Resilient, Non-Productive Actions** |
|---|---|
| Acknowledging design failure when it occurs | Denying that failure occurred by ignoring proper testing processes |
| Trying again | Giving up or losing interest<br>Seeing the task as being too difficult |
| Engaging in failure analysis | Making changes to design without planning or thinking carefully |
| Focusing on improvement | Staying with the original failed design |
| Working effectively as a team<br>Seeking help from peers and looking at other teams' designs | Engaging in negative team dynamics<br>Focusing on competition (worrying about performing less well than other teams) |
| Using the EDP (engineering design process) to guide next steps<br>Referencing background information to inform next steps | Ignoring background information that could inform next steps |
| Asking for help from the teacher | Seeking the "right answer" from the teacher |
| **Positive Emotions / Identities** | **Negative Emotions / Identities** |
| Expressing a positive emotion<br>Not appearing to take on a failure identity | Expressing a negative emotion / failure identity<br>Not appearing to care |

Table 2.
Summary of teachers' responses to students whose designs have failed from previous studies (Lottero-Perdue, 2015; Lottero-Perdue & Parry, 2015).

| Categories | Teacher Responses |
|---|---|
| General Interventions | (Before design failure occurs) Forewarning students that failure may occur<br>Offering general encouragement<br>Asking students questions |
| Specific Interventions | To establish that design failure has occurred through proper testing procedures:<br>• Reminding students about proper testing procedures and constraints<br>• Offering judgment about the success or failure of student designs<br>After design failure has occurred:<br>• Prompting engagement in the EDP, especially the improve step:<br>○ Encouraging students to consider how to improve<br>○ Encouraging students to engage in failure analysis<br>• Encouraging students to use peers as resources:<br>○ Encouraging students to work more effectively in their teams<br>○ Encouraging students to observe others' designs<br>• Encouraging students to make connections:<br>○ Helping to connect design failure or next steps to real world engineering and technology<br>○ Encouraging students to reference background information<br>• Providing direct advice and guidance about next steps |
| Non-Interventions | Refraining from offering judgment about the success or failure of the design<br>Refraining from intervening<br>Offering general encouragement only when necessary |

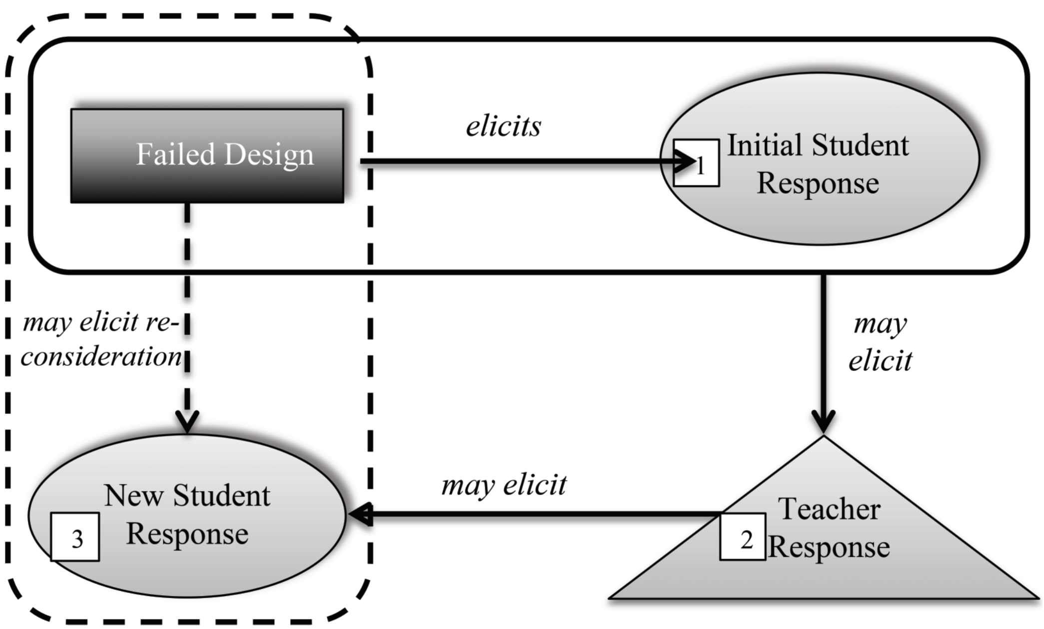


*Figure 1.* Model of dynamics between teacher and student responses to student design failure.

## Study Context & Participants

The present study is part of a larger study, the Exploring the Efficacy of Elementary Engineering (E4) Project. In what follows, we begin by describing the E4 Project and its participant selection process. We then discuss the professional development (PD) and curricula used in the project. We end the section by describing the present study's focus on failure, and how this topic has been addressed within the project for study participants.

### *The E4 Project Context and Participants*

The E4 Project examines the impact of two engineering curricula on students' interests, attitudes, and learning related to engineering and science. One of these curricula is EiE;

Table 3.
EiE engineering design process (EDP) steps (EiE, 2017).

| EDP Step | **Description of Step** with *Opportunities for Design Failure* Identified |
|---|---|
| Ask | What is the problem? How have others approached it? What are your constraints? |
| Imagine | What are some solutions? Brainstorm ideas. Choose the best one. |
| Plan | Draw a diagram. Make lists of materials you will need. |
| Create | Follow your plan and create something. Test it out! (*Opportunity for Design Failure*) |
| Improve | What works? What doesn't? What could work better? Modify your designs to make it better. Test it out! (*Opportunity for Design Failure*) |

the other is not commercially available. A four-year effort, the E4 Project began with a year of planning and teacher recruitment during which a total of 275 third, fourth, and fifth grade teachers from 172 schools were selected from a pool of about 600 applicants to participate. These teachers were from three regions in the eastern United States—Massachusetts, Maryland, and North Carolina—had not taught engineering in the past, taught a science unit of instruction that was related to content in the E4 Project units, and agreed to teach their assigned E4 Project unit(s) for two years consecutively (Year 1, 2013–2014; Year 2, 2014–2015).

Once selected, schools were randomly assigned to either the EiE curriculum (90 schools) or the comparison curriculum (82 schools); random selection ensured that school demographic variables were similar for each curriculum. There were 135 teachers assigned to teach the EiE curriculum, which is the curriculum of focus for the present failure study. Demographics for EiE-assigned schools were as follows: 13 percent urban, 7 percent town, 38 percent suburban, and 42 percent rural; 72 percent eligible for Title I funding; mean percentage of white students was 61 percent, with a standard deviation of 27 percent; 17 percent mean for African American students, 21 percent standard deviation; 14 percent mean for Hispanic students, 14 percent standard deviation. Of the 135 EiE teachers who began the project, 114 completed Year 1, and 75 completed both Year 1 and Year 2.[1]

All teachers in the E4 Project took part in providing and gathering data for the project. This included generating logs describing what was taught during each lesson, and administering and collecting pre- and post-assessments and surveys. In addition, 26 E4 Project teachers across the three regions were selected to have their classrooms be Classroom Intensive Observation (CIO) sites in which classroom activity was video recorded, and teachers and students participated in interviews.[2] By the end of Year 1, 23 teachers had fully participated as CIO site teachers, 16 of whom taught EiE curriculum. In Year 2, there were 15 CIO site teachers; 12 taught the EiE curriculum.

### *E4 Project and the EiE Curriculum*

Roughly half of E4 EiE teachers taught one "assigned unit" per year: geotechnical engineering, environmental engineering, electrical engineering, or package engineering (EiE, 2011a, 2011b, 2011c, 2011d). The other half taught two units: a civil engineering unit that was taught prior to teaching the assigned engineering unit (EiE, 2011e).[3] Similarly, half of the comparison curriculum teachers taught one unit and half taught two; the engineering topics were the same as for EiE teachers. Each assigned engineering unit was connected to science content that teachers taught in their regular instruction prior to teaching the assigned engineering unit. For example, teachers taught students an electricity unit prior to teaching the EiE electrical engineering unit.

Each EiE unit explicitly addresses and has students engage in an engineering design process (EDP) designed for elementary learners (Table 3). Students are introduced to the EDP in the beginning of the unit via a storybook. The storybook situates a child who encounters a problem, meets an engineer, learns about the particular engineering field of emphasis in the unit, and learns and implements the EDP. After reading the storybook, students gain more knowledge about the engineering field, and then learn essential background information in preparation for the unit finale: an engineering design challenge. Students use the EDP during this challenge, giving the process explicit attention as they work through it.

### *E4 Project PD*

In order to learn to teach their engineering unit(s) of instruction, E4 Project teachers participated in a required, three-day PD experience in the summer prior to Year 1. This PD focused on learning the units, and being introduced to the E4 Project study and data collection procedures. An optional one-day follow-up PD session was provided at

[1] See previous work from the authors for additional detail regarding eligibility and recruitment (Lottero-Perdue & Parry, 2014, this JPEER issue).

[2] For additional CIO site selection details, see Lottero-Perdue and Parry (2014, this JPEER issue).

[3] For a more detailed discussion of these EiE units, see Lottero-Perdue and Parry (2015) or go to www.eie.org.

the end of Year 1, with approximately two-thirds of E4 Project teachers attending those sessions. This largely served as a way for teachers to share experiences and tips, and for E4 EiE Project teachers, as a way to reinforce teacher questioning strategies and the EDP.

### *The Present Failure Study*

The present study focuses on teachers' reflections about design failure after Year 2 of the E4 Project, and includes survey and interview data collected at the end of this year. As previously mentioned, only teachers who taught EiE curriculum were included for participation in this study. Thus, the total possible participants in the study included the 75 E4 EiE teachers, which also included the 12 EiE CIO site E4 teachers who completed Year 2.

The teachers in the present study had been exposed to ideas about failure prior to contributing to the Post-Year 2 surveys and interviews. They had been exposed through: (1) PD; (2) the EiE teacher guide; and (3) previous survey questions and interviews from our past work (Lottero-Perdue & Parry, 2014, 2015). We used "exposed" here to suggest that while teachers encountered fail words and had some discussions about failure, these were not intensive, focused efforts to insist that teachers use fail words, teach failure as an explicit concept, etc.

During the first required PD experience for the E4 Project, failure was not addressed as a separate topic of discussion. The sole way in which failure was addressed during this initial PD was when it arose as teachers learned to teach the EiE units of instruction. Explicit mention of failure was relatively rare, with most teacher guides using between two and five fail words (out of approximately 130 pages of text) (EiE, 2011a, 2011b, 2011c, 2011d). The exception was the civil engineering unit in which 30 fail words were used, in large part since bridges were tested to failure in the unit (EiE, 2011e). The broad idea that designs may fail (or not work, or not meet criteria) was also a part of the EDP that all E4 EiE teachers learned during PD.

Failure was discussed as part of the optional follow-up PD. Teachers watched a short video of a teacher who helped students engage in failure analysis—i.e., figure out how and why their design failed—and the improvement process. Although she did not use fail words, questions posed to the follow-up PD participants after the video asked how the teacher encouraged her students to "persevere through failure." Also relevant to failure, albeit not by the use of fail words, teachers were asked to address multiple questions pertinent to the units they taught, including: (1) How did you respond to students when their designs were not successful? (2) What did you say? and (3) What did you try not to say?

Finally, all E4 Project teachers had some exposure to our questioning about failure in engineering education when they completed a Post-Year 1 survey approximately one year prior to the Post-Year 2 survey of focus for this study. There were six failure-related questions on this survey, which included 21 total questions. Additionally, all of the CIO site teachers who participated in the present study had participated in Pre-Year 1 and Post-Year 1 in-depth interviews, each of which included between 15 and 30 minutes related to failure.[4]

## Research Questions & Hypotheses

The present study considers how elementary teachers who have taught one or two units of the EiE curriculum for two years, reported: students' responses to design failure; the ways in which they, the teachers, supported students whose designs failed and used fail words; and their (teachers') own perspectives about failure. It also explores how teachers' supportive strategies, fail word use, and perspectives may have changed from the first to the second year of instruction. Qualitative research questions, descriptive quantitative research questions, null hypotheses, and a mixed-methods research question all provide direction for this mixed-methods study. To avoid cumbersome wording in the questions and hypotheses that follow, we did not include phrasing such as "*How did teachers report* students' responses to design failure?" However, we acknowledge that in this study we are indeed exploring data based upon teachers' reports via interview and surveys.

Qualitative Research Questions (and overarching questions for the study):

1. How did students respond to design failures during Year 2?
2. How did teachers support students whose designs failed in Year 2? How does this compare to the support they provided in Year 1?
3. What broad messages did teachers send to students about design failure? How are these related to their perspectives about failure?
4. How did teachers describe the EiE curriculum as a means to allow students to learn from failure and persevere in the face of setbacks?
5. How did teachers use fail words in Year 2? How does this compare to their use of these words in Year 1?

Quantitative Descriptive Questions:

1. How comfortable were teachers in supporting students when their designs failed in: (a) Year 1; and (b) Year 2?
2. How comfortable were teachers in using fail words during engineering instruction (a) Year 1; and (b) Year 2?
3. How important did teachers consider the EiE curriculum to be in: (a) providing opportunities for students to learn from failure; and (b) providing opportunities for students to persevere in the face of setbacks.

[4] For more details about these survey and interview questions, see (Lottero-Perdue and Parry, 2014, 2015, this JPEER issue (7.1)).

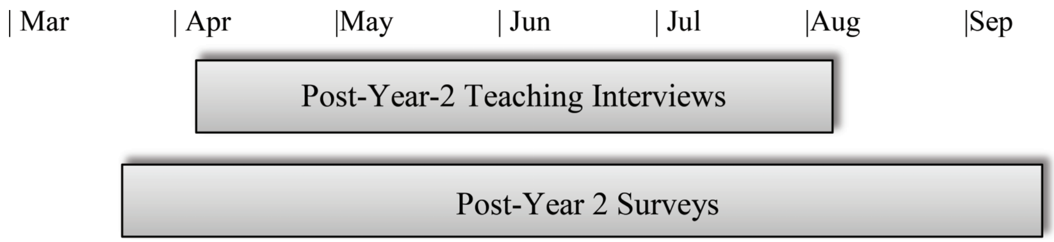


*Figure 2*. Data collection during/after Year 2 within the convergent mixed-methods design.

Null Hypotheses:

$H_{01}$: There is no difference between teachers' comfort with supporting students when their designs failed in Year 2 versus Year 1.

$H_{02}$: There is no difference between teachers' assessments of the importance of the EiE curriculum on providing opportunities to learn from failure or persevere in the face of setbacks.

$H_{03}$: There is no difference between teachers' comfort with using fail words during engineering instruction in Year 2 versus Year 1.

Mixed-Methods Research Question:

> How does the qualitative data gathered via interviews and surveys extend and elaborate quantitative survey findings regarding teachers' support of students when their designs fail, use of fail words, and broad perspectives about failure?

## Methods

In this study, we draw from both pragmatic and constructivist worldviews. Our pragmatic mindset encourages us to use whatever tools available to explore our research questions, be they qualitative or quantitative in nature (Creswell, 2014; Tashakkori & Teddle, 2003). For this particular study, these tools include the survey and interview data; however, our broader research effort also includes classroom video and student interview data. The mixed-methods approach that is common for pragmatism balances the benefits of quantitative research (e.g., the ability to generalize) with that of qualitative study (e.g., the ability to uncover complexities) (Creswell, 2014).

We have designed and analyzed the qualitative aspects of the study utilizing a constructivist worldview. In this worldview, no single reality exists; rather, there are multiple realities experienced by study participants (Creswell, 2014). Patterns and understandings emerge as researchers study participants' perspectives. This investigation occurs not from an objective distance, but rather from a closer, embedded position within participants' places of practice (Creswell & Plano Clark, 2011). We are indeed embedded in this way as the sole qualitative data collectors for two of the three E4 Project regions, and PD providers for these regions. This has enabled us to get to know the project teachers and students, especially within the CIO sites in our respective regions, and the project units extremely well.

Our study uses a convergent parallel mixed-methods design that emphasizes qualitative methods (QUAL + quan) (Creswell & Plano Clark, 2011). Data collection occurred in an overlapping timeframe between mid-March and mid-September of 2015 (Figure 2), after which data analysis ensued. We conducted quantitative and quantitative analysis separately, and then considered results of both analyses to identify instances of divergence and convergence (Creswell, 2014; Creswell & Plano Clark, 2011).

### *Survey Design and Data Collection*

The Post-Year-2 surveys (hereafter: surveys) were the final surveys for all teachers on the E4 Project. Thus, many questions—183 independent, Likert-scale questions; 5 multiple choice questions; and 17 open-response questions—were used to explore teacher perspectives and experiences regarding multiple aspects of the project. The surveys were delivered electronically to all E4 Project teachers, and several electronic reminders were given to teachers to complete them. There was a 99 percent response rate for survey completion among the 75 E4 EiE teachers of focus in this study who completed both years of the E4 Project.

The purpose of the failure questions on the survey was to explore whether and to what extent teachers increased in their comfort with helping students navigate design failure and using fail words across their time on the E4 Project. Additionally, we were curious about how teachers perceived the importance of the EiE curriculum in creating experiences for students to learn from failure and to persevere in the face of setbacks.

Altogether, there were seven failure-related questions on the survey, six of those were Likert scale questions, and one was an open response question. One of the Likert scale questions explored teachers' comfort "supporting students when their designs fail[ed]" last year, the first year of the project, on scale of 1 (not at all comfortable) to 10 (extremely comfortable). Another, listed on the same page of the survey, asked the same question yet with regard to this, the second year of the project. Together, this pair represented an ecosystem rating scale to get a sense of teachers' relative comfort in supporting students when their designs failed in Year 1 as compared to Year 2 (Suskie, 2009). Similarly, a pair of questions explored teachers' comfort in Year 1 as compared to Year 2 "with using words like fail or failure during engineering instruction." These two pairs of questions were preceded by another pair not related to failure that inquired about comfort "teaching engineering" this year as compared to last. After these three pairs of questions were asked, teachers were asked to "explain your ratings of your comfort with engineering" in an open-ended text box; responses to this question had the potential to address the topic of failure.

Two additional failure-related questions on the survey inquired about the extent to which the following aspects of the EiE curriculum contributed to student learning: "providing opportunities for students to learn from failure," and "providing opportunities for students to persevere in the face of setbacks." Likert-scale responses ranged from 1 (not at all important) to 10 (critical).

### *Survey Validity and Reliability*

This was the first time that the seven aforementioned failure-related survey items have been used. We did not conduct reliability tests for the six quantitative items. Despite this potential shortcoming, we feel that the items, which were iteratively written by the first author and reviewed and edited by many members of the E4 Project team, were clear and unlikely to be misinterpreted by the project teachers. Furthermore, the team conducting this iterative, collaborative item-development process has substantial elementary engineering curriculum writing, PD design and delivery, and classroom research experience, all of which contribute to a high degree of content validity. With regard to construct validity, the direct nature of the questions we asked addressed the constructs we sought to measure, i.e.: how teachers' report their comfort this year and last with helping students to navigate design failure and using fail words, and the extent to which the curriculum was important in helping students learn from failure and persevere in the face of setbacks.

### *Survey Data Analysis—Quantitative & Qualitative Methods*

We used a combination of descriptive and inferential statistics to analyze the quantitative data. Given that these data arise from 10-point Likert scale questions, we report our descriptive findings using frequencies and medians. We performed a Kolmogorov–Smirnov test on each data set, determining that the data were not normal. Thus, we employed nonparametric analytical methods, specifically, the Wilcoxon Signed Ranks test, to draw comparisons across items (e.g., when comparing teachers' Year 1 versus Year 2 comfort with using fail words) (de Winter & Dodou, 2010). Two-tailed significance at levels less than or equal to 0.05 were reported; effect sizes were calculated for significant differences. Our goal is to use these analytical procedures to ascertain the perspectives of elementary teachers who have taught EiE units of instruction for two years; however, we recognize that the non-random nature of our study population may not necessarily reflect the perspectives of all third, fourth, or fifth grade teachers.

Given that the open-ended survey questions broadly asked teachers to explain their comfort ratings (and not specifically with respect to failure), our first level of qualitative analysis involved determining whether or not each teacher's response included ideas about failure. The second level of analysis was to organize the ideas and messages (i.e., codes) across those responses that directly (24 percent of survey respondents) or indirectly (4 percent) attended to failure. Three major codes and 17 sub-codes emerged from analysis of these "failure-related open responses". Both levels of analysis proceeded as follows: the first and second author reviewed all 74 responses and conducted the first and second levels of analysis independently; the co-authors discussed discrepancies and consistencies in their analyses and negotiated a final list of failure-related open responses and a final code list; and each failure-related open response was reviewed one more time to ensure researcher agreement about coding. We used the spreadsheet program, Excel®, to assist with this process.

### *Interview Design and Data Collection*

Of the 12 CIO site participants who taught the EiE curriculum in Year 2 of the E4 Project study, ten participated in interviews (rate of participation: 83 percent) in the late spring and summer following participants' second year of teaching. We conducted five of these interviews, and another E4 staff member conducted the remainder. Three interviews were conducted in via a face-to-face format, and the rest took place over the phone. Interviews lasted between 30 minutes and two hours and were audio-recorded and later transcribed.

Interviews were semi-structured, utilizing an interview protocol that allowed for follow-up questions to encourage elaboration (see Appendix for interview protocol) (Spradley, 1979). There were approximately 30–35 questions on the interview that provided data for the present study. This question count includes sub-questions; the range accounts for those teachers who taught two units and thus, were asked additional questions. Interview topics included:

- Teachers' comfort with and implementation of engineering in Year 1 versus Year 2.
- The impact (positive or negative) of the curriculum on students.
- The extent to which students' designs were successful.
- The extent to which students' experiences engaging in EDP were successful.
- Students' reactions to design failures.
- Teachers' responses (specific and broad) to those reactions.

- Teachers' comfort using fail words during instruction in Year 1 versus Year 2.
- Teachers' perceptions about the extent to which the curriculum provides opportunities for students to learn from failure.
- Teachers' support of students' design successes and failures in Year 1 versus Year 2.

Five interview questions were designed to elicit teachers' elaboration of particular survey responses. Prior to conducting each interview, each participant's responses to five survey questions were documented on the interview protocol for reference.

### *Interview Data Analysis*

All ten interviewees were assigned pseudonyms. We then engaged in an iterative, collaborative analysis of the interview data and generation of a set of codes to describe the data (Creswell, 2014; Tesch, 1990). Four rounds of analysis were as follows:

Round 1: The ten interviews were divided between the co-authors: Batch 1 for Lottero-Perdue; Batch 2 for Parry. Each co-author read and generated codes independently. Co-authors then met for a discussion of emergent codes, developing Code Set 1.
Round 2: Lottero-Perdue applied Code Set 1 to Batch 1. Parry applied Code Set 1 to Batch 2. Co-authors met to discuss the results of this process and to discuss emerging codes. The code set was revised again, forming Code Set 2.
Round 3: Lottero-Perdue applied Code Set 2 to Batch 2 in light of Parry's coding; in so doing, Lottero-Perdue either agreed with, changed, removed, or added to Parry's coding of Batch 2. The same process occurred for Parry, who re-coded Batch 1. Co-authors then met to discuss this round of analysis and any changes in interview coding. The code set was revised again, forming Code Set 3.
Round 4: Lottero-Perdue then conducted a final round of coding by re-reading the entire set of interviews and codes from Round 3, and then connecting codes and interview text into the qualitative analysis software, HyperResearch™. This generated slight changes to the final coding of interviews and to the set of codes, creating Code Set 4.

Although Round 1 involved the use of codes that were clearly connected to interview questions or to codes and themes from our previous work (Lottero-Perdue, 2015; Lottero-Perdue & Parry, 2014, 2015, this JPEER issue (7.1)), our iterative process allowed for additional codes and themes to emerge from the data. Ultimately, 4 major codes—addressing the aforementioned four research questions—and roughly 70 sub-codes were used to describe the data.

A caveat regarding the presentation of findings from interview data: Throughout the paper, we will share percentages representing sub-code frequencies or frequencies of particular groupings of sub-codes. These are only used to give readers a sense of response frequency among interviewees. These numbers, however, are not meant to be interpreted with the same kind of statistical importance as are percentages for the aforementioned quantitative data. More often in our presentation of findings, we give a sense of the range of responses in our interview data, and utilize quotes from interviews to exemplify responses.

Finally, our role in this study is largely that of researchers, yet our involvement is close to that of participant observation (Saldaña & Omasta, 2017). Together, we conducted half of the interviews in the study, and spent over 15 hours in each of five of the ten teachers' classrooms gathering data. We have also provided PD to these and other teachers in the study. In many respects, our entrenched roles represent strength in that we are very familiar with the EiE units and with their implementation in these and other classrooms; we have also gotten to know these teachers quite well. We acknowledge, however, that this closeness to the teachers and their classrooms may also have downsides. Although we have attempted to analyze data with open and critical eyes, we may be inclined to interpret teachers' contributions and perspectives in a generous way, or we may be inclined to make connections in our analysis that may be overly interpretive. Knowing this, we have regularly and kindly challenged one another throughout our analytical process if, for example, we suspected that one co-author felt that the other was reading into a teacher's language too much.

### *Mixed-Methods Analysis*

In the section that follows, we meld together quantitative and qualitative survey and interview findings to present a set of cohesive answers to the research questions. In this way, we have mixed not only our data collection methods, but also the way in which we have come to understand teachers' reflections on design failure and their use of fail words.

## Findings

The findings shared here correspond to the five aforementioned research questions of the study, and are as follows: (1) student responses to design failures; (2) teachers' reflections on supporting and responding to student design failures; (3) teachers' broad messages to students about failure; (4) teachers' perspectives on how the EiE curriculum addresses failure and perseverance; and (5) teachers' fail word use. Survey and interview data are interwoven throughout these sections.

Table 4.
Positive student responses to design failures mentioned by interviewees and documented in previous studies (Lottero-Perdue, 2015; Lottero-Perdue & Parry, 2015).

| Positive Student Responses | Example | % Interviewees |
|---|---|---|
| Trying again | "they were eager to try again" (Cheryl) | 80% |
| Expressing a positive emotion | "they … took it in good spirit" (Diane) | 70% |
| Working effectively as a team | "[the team] went back to the drawing board and kept talking and talking and talking …" (Elissa) | 50% |
| Engaging in failure analysis | "it was great to see them … trying to figure out what went wrong" (Shannon) | 50% |
| Focusing on improvement | "they're already thinking about what they can do to improve the next one" (Teresa) | 50% |
| Looking at other teams' designs for ideas | "once they saw everybody else's and did the gallery walk … it sparked some motivation" (Crystal) | 40% |
| Using the EDP to guide next steps | "they used that design process because that's what they were supposed to do and just redid it" (Kathryn) | 30% |
| Referencing background information to inform next steps | "they talked about the bridge types that we learned about and the different parts of the bridge, and what they could do to change [their design]" (Shannon) | 20% |

### *Students' Responses to Design Failure*

The interviewees in this study—Cheryl, Diane, Elissa, Shannon, Crystal, Teresa, Kathryn, Janet, Joy, and Tammy (all pseudonyms)—described students' responses to design failures; survey data did not address student responses to design failures. Most student responses described by interviewees ($N = 10$) were consistent with those student responses identified in previous failure studies pertinent to the first year of the E4 Project (Lottero-Perdue, 2015; Lottero-Perdue & Parry, 2015). Many of the student responses shared by teachers fit neatly into two contrasting categories: positive, resilient, or productive responses to design failure (shown in Table 4); and negative, non-resilient, or non-productive responses (Table 5).

Positive student responses included: trying again, expressing a positive emotion, working effectively as a team, engaging in failure analysis, looking at other teams' designs for ideas, focusing on improvement, using the EDP to guide next steps, and referencing background information to inform next steps. Negative student responses included: expressing a negative emotion, engaging in negative team dynamics, giving up, making changes to the failed design without planning or thinking carefully, staying with the original failed design, ignoring or not properly considering background information, copying another group's solution, and being in denial that failure had occurred. Other responses, however, were more difficult to organize in this positive/negative dichotomous way. For example, two interviewees (20 percent) mentioned that students were often surprised that their planned design ideas did not work, a student response code that we had not observed in prior studies. At times, this was coupled with "disappointment" or "bewilderment"—clearly negative emotions—yet the act of surprise itself may not necessarily be negative, perhaps inspiring curiosity or a desire to try again. Thus, the student response of *surprise* has been left out of both tables.

Included in both tables—positive and negative student responses, respectively—is the idea that design ideas may arise from observing or "copying from" our peers. In most cases where this was mentioned, teachers were pleased that students observed others' designs to inform next steps in the EDP after design failure. However, in one case, Diane suggested that the success of one team in the class led most of the other teams to effectively copy that team's design. From Diane's perspective, the other teams supplanted their own reasoning and use of background information with a quick fix to make a bridge that looked like that of the most successful team in the room. For Diane, this was akin to another negative response, "making changes to the design without planning or thinking carefully," also included in Table 5. The action of students observing others' designs in the room may be regarded as either a positive or a negative response to design failure.

Another student response code that was difficult to capture in the tables was what we have entitled: *expecting success and avoiding failure* (by 40 percent of the interviewees). We include these separately because they are pre-emptive in nature—not responses after design failure has occurred, but rather dispositions of students that teachers mentioned in which students approach engineering design challenges with either an assumption that they will succeed *or* a strong desire to avoid failure. We have observed these pre-emptive student responses in previous studies (Lottero-Perdue, 2015; Lottero-Perdue & Parry, 2015). Joy and Elissa mentioned students who assume that the designs they have created on paper will translate into

Table 5.
Negative student responses to design failures mentioned by interviewees and documented in previous studies (Lottero-Perdue, 2015; Lottero-Perdue & Parry, 2015).

| Negative Student Responses | Example | % Interviewees |
|---|---|---|
| Expressing a negative emotion | "some of them took it really to heart and they were really upset" (Diane) | 60% |
| Engaging in negative team dynamics | "I had some that would be like, 'man, it's your fault,' or blame the other person" (Crystal) | 30% |
| Giving up | "she just crossed her arms and just quit" (Cheryl) | 30% |
| Making changes to design without planning or thinking carefully | "when they see a problem, then they immediately jump in and get more materials to fix it … they're not as disciplined about … thinking '… let's think of all the things that went wrong and now make a new plan'" (Janet) | 30% |
| Staying with the original failed design | "he thought that this was the design … and he was just going to stick with it and try to make it work … [but] it didn't work in either trial and then he was done" (Diane) | 20% |
| Ignoring or not properly considering background information | "with the one group [with circuit that was continuously on]—they probably had four or five tries and just weren't understanding the concept [of how a switch worked, addressed earlier in the unit]" (Tammy) | 20% |
| Focusing on competition | "there was jealousy and competition within the group" (Shannon) | 20% |
| "Copying" another group's design solution | "once table two … had that success [implementing an arch bridge], then everybody wanted to see what that success was all about and then, all of the sudden … everybody had an arch" (Diane) | 10% |
| Being in denial that failure has occurred | "[one] group was in denial that their design could not succeed as they envisioned because clearly they tried to manipulate the situation to work in their favor [reporting inaccurate test results]" (Joy) | 10% |

success when created and tested—students who were subsequently surprised when their design ideas did not work. Diane suggested that many of her students assume that they will be successful, sharing that her students were "in love with success." Cheryl mentioned "one or two kids in the mix … [who] didn't even want to attempt to do it [the design challenge] unless they knew exactly how to do it the right way." One of these students gave up when her first design idea did not work.

In addition to the student response code, surprise, which this study uniquely offers, two additional codes from the present study provide novel contributions to the research literature. We asked teachers if they were surprised by any of the students' reactions to design failures. Of the 10 interviewees, 80 percent shared ways in which students' responses were surprising. One mentioned a group of students that did not work well together, yet she expected that they would. Another anticipated that some of her students would give up, but, she offered: "I didn't feel like this happened at all." Beyond these observations, interviewees mentioned two notable surprises. First some students who are normally academically successful in school were not as successful with respect to the design challenge, and were frustrated and upset when their designs failed (40 percent of interviewees). For example, Shannon offered:

> I guess there was a little surprise at the student that was so frustrated. However, he was used to achieving high, so I guess it makes sense that he would be upset that his bridge wasn't the best. I was a little taken aback that he was so upset. (Shannon)

Second—and as Cheryl articulated—some students who are not often academically successful in school were very successful with respect to the design challenge and persevered when their designs failed (40 percent):

> … there was a lot of kids that didn't get it the first time, but aren't really involved in school and don't care a whole lot about school otherwise. But they all seemed really engaged and real excited to try. I did see that. There were some kids that don't have their homework every day, but they were eager to try several times to get the thing to work, so that was cool. (Cheryl)

In all, 70 percent of the total pool of interviewees made one or both of the above observations about being surprised by the responses of either typically high achieving or typically struggling students with respect to design failure and the challenges of the EDP.

When asked how students' reactions to design failures compared to their reactions when they were not successful in other subject areas, 60 percent of interviewees shared that students reacted similarly, and 30 percent noted differences. Joy was the only interviewee in both groups, offering that while some reactions (e.g., competition) were

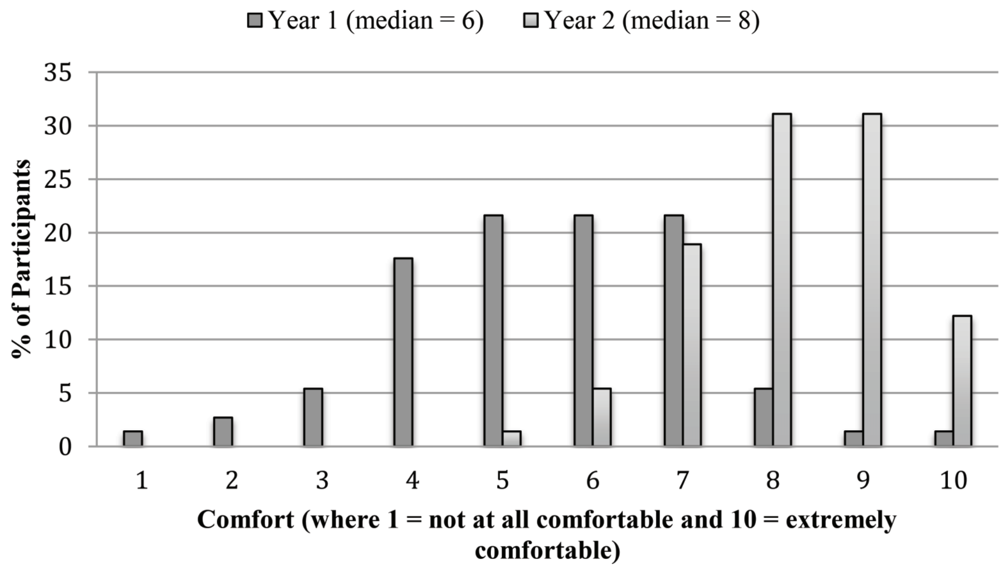


*Figure 3*. Teachers' ($N = 74$) comfort with supporting students when their designs failed during Year 1 and Year 2 as reported on the Post-Year-2 surveys.

similar, others were not. She observed one student who is often highly frustrated, "quick to get upset," and "teary" with respect to mathematics and other classes, but who did not exhibit these behaviors even as her group struggled to design a bridge. Joy wondered:

> Maybe it's because it is something tangible. It's something that you're taking ownership of … Maybe she's just more motivated to do well and not get upset because getting upset takes time away from being able to try out something else. Maybe she'll be able to have more self control. Also I think working together with other girls, I think that helped her. It wasn't a one-person deal. It's not all on her, it's a collaborative effort, and they worked really well together. (Joy)

Similarly, Elissa and Shannon saw that failure was easier for students to manage for engineering as compared to other subjects given that the EDP guaranteed an improvement step. For example, Elissa offered:

> I think in general they showed more maturity with failure in engineering and knew that they would have a chance to improve, so they didn't really focus so much on the failure whereas other times, if a kid doesn't get accepted into the literary magazine at school, they're really bummed out and you can feel the effects of that for much longer than the feelings of failure from engineering. (Elissa)

Contrastingly, Joy also observed more disappointment in some of her students when their designs "didn't work out the way they had envisioned" as compared to when they struggled in mathematics or reading.

*Teachers' Reflections on Supporting and Responding to Students when their Designs Fail*

When teachers were asked on the survey to indicate their level of comfort on a Likert scale from 1 (not at all comfortable) to 10 (extremely comfortable) *this* year, Year 2, with supporting students when their designs failed, the median response was an 8; the median response when reflecting on *last* year, Year 1, was a 6. The difference between the two is significant, with an effect size of 0.60, rejecting $H_{01}$; see Figure 3 for a graph depicting response frequencies.

Three interviewees (30 percent) made specific reference to their increased comfort supporting students as their designs failed in Year 2. All three mentioned some variation of Tammy's assertion, "I knew what to expect." Diane was more specific:

> This year, having seen the failures last year, I think I was a little more critical of the failures this year. I think I really tried to push them in a direction of think about this, think about that. Where last year, I almost felt like I didn't have—I was treading water so I'm not sure what was advice … was … I didn't want to step over that line where, this year, I felt a little more comfortable when they failed. (Diane)

Additionally, of the 21 survey respondents who provided a failure-related open response to elaborate their quantitative responses, 19 percent discussed their growth as a teacher in helping students to navigate design failures and struggles during the EDP. One teacher offered: "Being able to admit things didn't work without sugar coating it was a relief to me and to the students. They are very accepting of failure when they have a chance to make things better." Another shared: "After practicing the first year, I feel much more comfortable teaching engineering and dealing with when a child fails at first." Contrastingly, one survey respondent admitted that: "Failure and fail is something new to me … I still have a ways to go to make students comfortable about failure." This admission seems to go beyond discomfort with using fail words (the focus of the last part of the findings section), to include the failure experience itself.

Interviewees described the ways in which they responded to students and teams whose designs had failed. These responses were very similar to those identified in previous work and in Table 6. These responses included general strategies, most notably asking students questions, offering encouragement, and reminding students that it's okay to fail. Teachers also reported that they used more specific responses, including encouraging students to: improve, engage in failure analysis, observe others' designs, reconsider relevant background information, work more effectively as team members, follow the EDP, and remember that it is normal for engineers' designs to fail.

In addition to the responses to failure in Table 6, two teachers suggested that they were available to sense and manage students' emotions as they engaged with design failure. Tammy served as a sort of barometer to sense the level of frustration in her classroom, saying, "… before anyone started to reach frustration levels … I would step in." She described further:

> About not letting kids reach frustration, I don't necessarily mean that I never let them get frustrated. I guess it's the shutting down point because there's a difference between letting them experience frustration with their failure and then that point where they're done and they're not going to do anything. I'd let them get frustrated but I would intervene before that shut down point because they're ten years old and they still do that. (Tammy)

This stepping in might take the form of suggestions to look at what other teams had done, or offering up "a couple hints." Another teacher, Shannon, shared that she would sometimes "take a few in the hall who were crying."

In the course of discussing their responses to students whose designs failed, interviewees explicitly discussed or implicitly suggested the extent to which they intervened and directed next steps. Figure 4 captures this range in teacher directedness in two respects: (1) whether the teacher provided

Table 6.
Teachers' reported responses to students or teams whose designs had failed as mentioned by interviewees and documented in previous studies (Lottero-Perdue, 2015; Lottero-Perdue & Parry, 2015).

| Category | Teacher Response | Example | % Interviewees |
|---|---|---|---|
| *General Responses* | Asking questions | "I tried to do a lot of just asking questions, and if they asked me something, I tried to respond with another question for them." (Cheryl) | 70% |
| | Offering encouragement | "I just kept encouraging them and telling them 'You can do it. Just keep trying." (Crystal) | 30% |
| | Suggesting that it's okay to fail | "Every time their circuits don't work or their bridge doesn't hold weight or their car doesn't go across, we would name it a failure meaning they—then you just do it again. It was really not a big deal if it didn't work the first time." (Tammy) | 20% |
| *Specific Interventions*—Encouraging students to: | … Improve | "I think I try and refocus them to think about what you're doing, think about … what you can change. Once something happens, you can't undo [it] … but that's why we're doing an improvement." (Diane) | 60% |
| | … Engage in failure analysis | "I kept pushing them to go back and look at what in particular went wrong." (Janet) | 40% |
| | … Observe others' designs | "I found myself constantly repeating to them to look at the whole design, find out all the failures … take a look at other people's designs, how are they actually maybe not having a problem that you're having." (Janet) | 40% |
| | … Re-consider background information | "I reminded them of what we learned before to make whichever, the plant package or the bridge, successful." (Shannon) | 40% |
| | … Work more effectively in their teams | "I keep reiterating how they need to … work with each other in a positive manner, and have each other's back." (Crystal) | 30% |
| | … Reference or use the EDP | "[I would ask:] 'What do we do now?' We would look back at the whole engineer design process. I think that's the key to keeping the kids invested … it's a work in progress, it's constantly being improved." (Kathryn) | 20% |
| | … Remember that this is what engineers do | "I kept saying: 'Sometimes they don't work out, but you just got to keep trying. This is what packaging engineers do.'" (Crystal) | 10% |

**High Teacher Direction** → **Low Teacher Direction**

| Offering Direct **Judgments** about Design Failure (mentioned by 20% of interviewees) | Refraining from Making **Judgments** about Design Failure (10%) |
|---|---|
| Example:<br>"I think I just [said] … like … "you were stable enough to have the car go across, but it [the bridge] wasn't strong enough." (Elissa) | Example:<br>"I kind of try to keep it … more open-ended … as opposed to '… I think your design worked well because you did this.' I try to get them to answer why their results were the way they were." (Joy) |

| Offering **Direct Suggestions** (60%) | Offering only **Minimal Interventions** (60%) |
|---|---|
| Examples:<br>"I think I really tried to push them in a direction of: think about this, think about that." (Diane)<br>"[I asked] 'Are you leaving enough room for the barge to be able to go underneath the bridge?' or 'Have you thought about how you're going to protect your land from the oil spill?'" (Teresa) | Examples:<br>"Inside, you're feeling like 'Don't use popsicle sticks! Use paper! …' [But] no, [I'll just say] 'Oh, why did you use that particular strategy? Why did you use that material?' and just hear their thinking instead of telling them what to do." (Joy)<br>Elissa would typically interject questions, and "oftentimes, they were able to start to think about it and I would leave because I could tell they were … on their way." (Elissa) |

*Figure 4*. Level of teacher intervention and direction provided by teachers when students' designs failed.

a judgment statement about the extent to which design failure occurred (addressed by 30 percent of interviewees) and (2) how directive teachers were with regard to moving forward after design failure had occurred (100 percent). Most interviewees reported using a range of approaches, from non-intervention to direct suggestions.

Interventions seemed to depend upon either the particular context (e.g., of a struggling group in a certain design challenge) or of a particular group of students. In one case, a team of students in Janet's class with "two strong personalities" was "just spending money buying supplies … [yet their] … bridge just wasn't working." Janet, their teacher, ultimately intervened to have the students "hold back" on purchasing more supplies until they had spent time giving more thought to their design. Reflecting on this, Janet suggested that this was more direction than she normally provides: "The only thing I would [normally] do is ask leading questions to kids, getting them to … stop and think about it, and that was maybe the only intervening that I would do with other groups." More generally, Tammy suggested that the degree of direction she provided students "depended on what I knew the students were capable of and … how much support they needed to experience the success all without giving them the answer." She suggested that this was just like any other kind of "differentiation that you use in any subject on how much support you give the students." Joy, who shared that she intervened only when necessary when she taught engineering and other subjects, offered a similar sentiment that: "some kids need more questioning and fine tuning than other kids do."

### *Teachers' Broad Messages to Students about Failure*

In interviews and in failure-related open responses on surveys, teachers shared some of their perspectives about failure. Of particular interest to this study were the occasions in which teachers asserted that they shared these perspectives with students as messages or explicit aspects of instruction. Unlike the previous section on teacher responses to student design failure, these messages did not appear to be in direct response to a certain student or team's design failure. Instead, the messages of focus in this section

Table 7.
Teachers' broad messages to students mentioned by survey respondents and interviewees. Perspectives marked with a * have been documented in previous studies (Lottero-Perdue & Parry, 2014, 2015, this JPEER issue (7.1)).

| Message to Students (and Teacher Perspective) | Example | % Open-Ended Survey Respondents ($N = 21$) | % Interviewees ($N = 10$) |
|---|---|---|---|
| Failure is a learning opportunity.* | "Failure is not a bad thing, we all learn from it, move on, and do better next time." (Survey Respondent E) | 33% | 10% |
| Failure leads to positive outcomes.* | "Failure was a term I used and explained to kids, but not in the same fashion used in engineering. Failure [in other subjects] happened and was not the end of the world, study harder next time, but failure in engineering means the elimination of one method and building a new plan. It is a positive thing." (Survey Respondent H) | 29% | – |
| It is okay to fail.* | "Based off of last' year's experience, I … set up the whole classroom regardless of subject that failure is okay … all the kids know the saying, 'It's okay to fail.'" (Tammy) | 19% | 30% |
| Failure is a normal part of engineering and the EDP. | "I just let students know that's what an engineer has to say to themselves. They have to say, '…it failed because it's not [meeting the criteria].' They justify it with that, and then … try to find a way to improve." (Shannon) | 10% | 20% |
| It is important to persevere: to try again and not give up if you fail.* | "I always tell students it's ok to fail and make mistakes as long as we learn from them and don't give up right away." (Survey Respondent A) | 10% | 20% |
| Just because your design fails, doesn't mean that *you* are a failure.* | "I try to make them … not feel like a failure at any point." (Kathryn) | 5% | – |

took on a broader nature, were often directed to the entire class, and may have been provided prior to, during, or after engineering design failure experiences. It is important to note that we did not explicitly ask teachers to discuss broad messages that they sent to students related to failure; rather, teachers shared messages in the course of elaborating their prior survey responses about comfort with teaching engineering or discussing their perspectives about failure in interviews (see Table 7).

While the frequencies with which teachers mentioned that they shared messages about failure with students were relatively low (in Table 7), teachers discussed their own beliefs in these perspectives with greater frequency. Interviewees held the following perspectives about failure, regardless of whether they stated that they shared these perspectives in a broad way with students: failure is a learning opportunity (70 percent); failure leads to positive outcomes (20 percent); it's okay to fail (50 percent); failure is a normal part of engineering and the EDP (30 percent); it is important to persevere (70 percent); and, just because your design fails, does not mean that you are a failure (10 percent).

Beyond the broad messages about failure shown in Table 7, four additional themes emerged regarding teachers' instructional approaches to failure. These four themes are: (1) equating mistakes as failures, (2) anticipating failure, (3) comparing failure in engineering to failure in other subjects, and (4) addressing failure differently for different groups of students. The first theme was that "mistakes" continue to be a compelling analogy for some teachers as they consider design failures and discuss these with their students as addressed in our previous work (Lottero-Perdue & Parry, 2014, this JPEER issue 7.1). One of three (14 percent) survey respondents who provided a failure-related open response shared:

> After teaching the science/engineering unit for the second year I've become more comfortable explaining what it means to redesign something that may have been a failure. As teachers we always discuss the fact that we learn from our mistakes. This way we can always learn to grow and better ourselves. (Teacher, Open-ended Survey Response)

Kathryn was another of these respondents, who was consistent in her use of equating mistakes and failures in her interview, e.g.: "What I try to explain to them is, 'It's important that you fix your mistakes.'"

A second theme was that teachers—now more informed in their second year of the E4 project—were able to prepare students for failure prior to engagement in the design process. This was evident in 14 percent of open-ended survey question respondents who provided a failure-related open response question, including:

> This year, I did more to prepare students that their ideas might not work the first time so they would know it was okay. (Teacher, Open-ended Survey Response)

Others, including Janet, an interviewee, shared similar sentiments. She described how "some of the work we've done in the classroom about dealing with failure" seemed to reduce negative responses such as "dramatics or people getting fuming [mad]" by students to design failure.

The third theme involved teachers comparing failure in engineering design with failure in other subjects, and bringing discussions of engineering approaches to failure into those subjects. Over half of interviewees (60 percent) engaged in this comparison, largely noting ways in which the failure and improvement process in engineering was similar to allowing students to fix mistakes or otherwise improve their work. Four interviewees (40 percent) mentioned having explicit discussions with students about failure across subjects. One of those was Kathryn:

> I explain to them, I use math as a good example, because sometimes you'll get various types of math problems on the test. You might only get one wrong, but if you do that one thing wrong on another test that has four or five of those problems, your grade's going to be a lot worse. The kids get it, and they understand it, and they roll with it. I just think it's good, because it makes them also conscientious with their work, and it makes them proof their work, and go back and see what they did wrong, and how they can correct it, and improve. It's like the engineer[ing] design process. (Kathryn)

Kathryn compared the iterative EDP to "go[ing] back" to mathematics work to correct it, improve it, and elevate their grades. Most interviewees (50 percent) who compared engineering design failures to failures in a specific subject used mathematics as that subject; two mentioned reading or writing (20 percent).

One unique contribution regarding subject comparisons is also worthy of note here. Elissa described that all other subjects at her "very academic school" had curricula that were "tailored to where the student is." She described how students were placed into reading groups according to their ability. She compared this with the EiE curriculum that, she said, was "not [tailored to where the student is]." Elissa elaborated, "It's right there and they're the ones that are sort of in charge of it." Our interpretation of Elissa's contribution here is that whereas the reading curriculum may scaffold learning for success, the EiE curriculum does not dictate students' ensured success, and instead, enables students to experience failure.

The final theme regarding teachers' broad messages and perspectives on failure is related to their ideas about how certain students should or can engage in failure experiences. Half of the interviewees discussed their perspectives on how different kinds of students should learn from failure experiences. Diane juxtaposed the needs of academically gifted students with students who tend to struggle in school. Gifted students, Diane suggested, need to be exposed to failure experiences, pushing them to learn from and improve beyond their first attempts. These students, who often prefer to do something once without revision or reflection, "can learn a bunch from failure." Cheryl shared a similar view that such students who typically "didn't have a hard time with a lot of things" needed to learn the life skill of how to recover from failures before "they get thrown into the real world." Contrastingly, Diane warned against exposing students who tend to struggle in school to too much additional failure:

> The more capable student … can let their creative juices [flow] when they need to improve and to redesign. They can really critically look at, okay, let's try this. Where, when you take the one who has failure on the mind, I think it's just [for that student]: "Oh, here's another example of something I can't do." (Diane)

She worried that such students might "internalize that I'm a failure," thinking "I can't do Math. I can't do ELA [English Language Arts]. I can't do this. I can't do that." Teresa described her students as a "a group that … fail[s] at a lot of things, but they're learning to deal with that failure." She saw their engagement in engineering design as a means for them to "see their success" and be a confidence-booster. It is important to note that this perspective was likely related to the high degree of success students had in their bridge challenge; this success was exaggerated since testing procedures incorrectly and inadvertently made design failure highly unlikely. (The teacher allowed for the bridge strength testing to occur on top of bridge piers, rather than on the widest bridge span; this is a common error in this curriculum.)

Tammy had a somewhat similar division of students as did Diane; however, there was a slight difference. Instead of identifying academically gifted students versus students who struggle, Tammy compared "kids who were born naturally better at science and figuring out how things work" to "students who were struggling." Her response to the first group was: "If they wanted to keep going, they could keep going." Her response to the second: "I let them struggle and tried as many times as they needed to." Interestingly, these responses seem similar. Later in her interview, she described how she employed the same kinds of differentiation moves she would use in any subject in order to provide just enough support to "experience the success … without giving them the answer."

### *Teachers' Perspectives on the EiE Curriculum Regarding Failure and Perseverance*

On the survey, teachers reported that the EiE curriculum was critical in "providing opportunities for students to learn from failure" (median of 10) and "providing

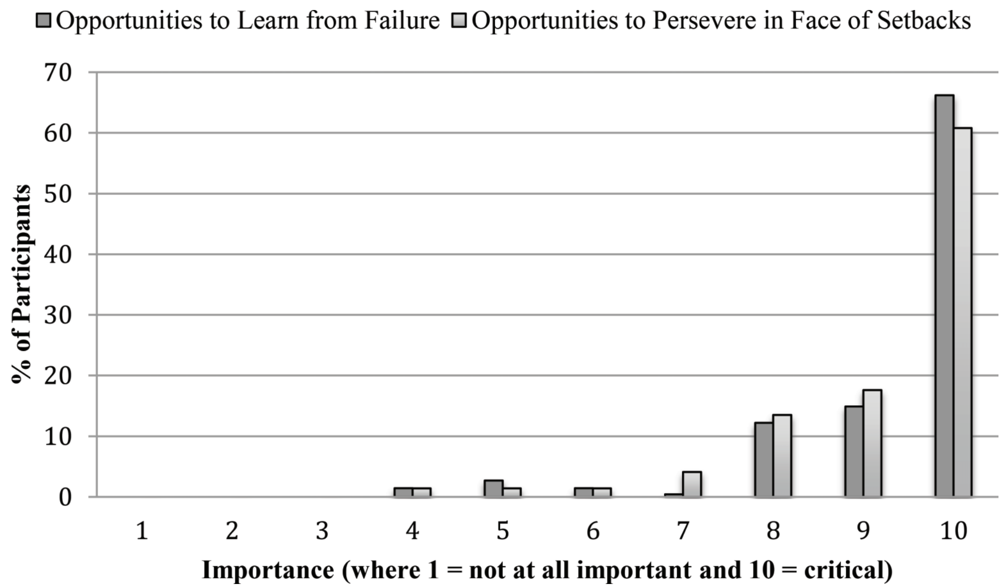


*Figure 5*. Teachers' ($N = 74$) responses regarding the importance of the EiE curriculum in providing opportunities for students to learn from failure or to persevere in the face of setbacks.

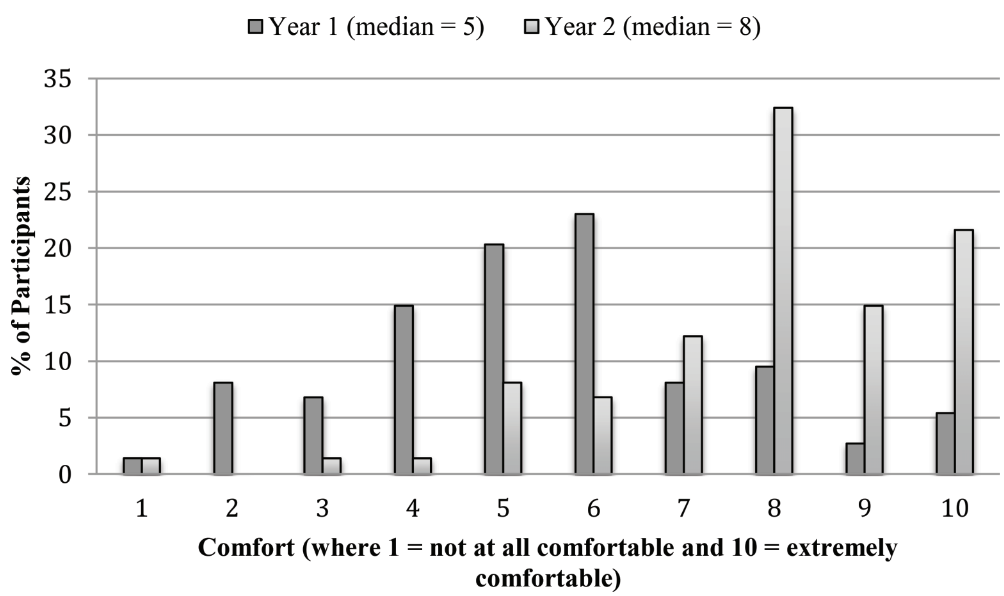


*Figure 6*. Teachers' ($N = 74$) comfort with using words like fail or failure during engineering instruction during Year 1 and Year 2 as reported on the Post-Year-2 surveys.

opportunities for students to persevere in the face of setbacks" (median of 10) on a Likert scale that ranged from 1 from 1 (not at all important) to 10 (critical). There was no statistically significant difference in the degree of importance teachers placed on the curriculum's contribution to learning from failure as compared to persevering in the face of setbacks, supporting $H_{02}$. Figure 5 shows the response frequencies for these two questions. These two aspects of the EiE curriculum were also prominent themes in teacher interviews, with 70 percent of interviewees holding perspectives on the importance of learning from failure and perseverance. These perspectives were also emphasized in the broad messages that teachers projected to their classrooms, as discussed in the previous section.

*Teachers' Use of Fail Words*

Survey data showed a significant increase in comfort level with the use of fail words. When teachers were asked how comfortable they were with using words like fail or failure during engineering instruction via a response between 1 (not at all comfortable) and 10 (extremely comfortable), the median response for *this* year, Year 2, was 8; the median response for *last* year, Year 1, was 5. The difference between the two is significant, with an effect size of 0.52, rejecting $H_{03}$; see Figure 6 for a graph depicting response frequencies.

Lending further support to these quantitative findings, 80 percent of interviewees expressed a high degree of comfort using fail words (rating their comfort in Year 2 as an 8 or higher). Diane was not in this group of interviewees who shared a high degree of comfort; however, she was also not uncomfortable, rating her comfort using fail words for both Year 1 and Year 2 as a 5 on the Likert scale. This is related to Diane's aforementioned concern using fail words or emphasizing failure experiences for students who are already struggling and may be inclined to identify themselves as failures. We also did not categorize Crystal in this group of highly comfortable fail word users, although her comfort with using fail words moved from a 4 to a 7 out of 10 (and in the interview, she felt that the score of 4 was probably too high).

Two survey respondents (10 percent) who provided a failure-related open response indicated that they still struggled with using fail words. These respondents suggested that they preferred using euphemisms (e.g., "didn't work") or simply avoiding the word by referring to the EDP and its steps (e.g., focusing on improvement, but not failure). One of these respondents admitted that s/he "struggle[d] a bit using the word fail," yet did share that s/he would say "failure is not a bad thing, we all learn from it, move on, and do better next time." Another respondent seemed to still hold onto the belief that student failure was reflective of poor teaching: "I rarely use the words 'fail' with lessons. I feel if student is not doing well, I need to teach better."

Crystal—who was only somewhat comfortable with using fail words—was, however, in a group of interviewees (60 percent) who indicated that their comfort with using fail words increased between Year 1 and Year 2. No interviewees decreased their use of fail words, and 40 percent said that their usage remained the same. One of those who increased in their comfort using fail words was Cheryl, who offered: "I did feel like I used it more this year, just because I was more comfortable using it myself." Teresa provided a rich discussion of her increased comfort:

> 'Fail' has always been a dirty word in school. You don't want to fail 5th grade, you don't want to be able to miss that opportunity to go to middle school. We used to be able to tell the kids, "If you fail the EOG [end of grade assessment], we're not going to send you to middle school." We would hold that over their heads to motivate them to try a little harder when it would get close to testing time. My view on that has changed a lot, because I was one who actually did poorly, especially in 3rd grade, in math. I had a really hard time with seeing all of those Xs on my papers and things like that, so I am a little sensitive to failure, because I know what it feels like to be the person who has all of those Xs on the paper and to know what it feels like when those papers go home and things like that. It's [failure is] something that I don't talk about a lot in the beginning, but now it's transformed and it's taken on a totally new meaning, because failure is part of life, and I'm seeing now through engineering that everybody is going to fail at something. (Teresa)

In addition to interviewees' assertions that their fail word use increased, two teachers who provided failure-related open responses (10 percent) also mentioned their growth in using fail words. One offered: "I became more comfortable talking with my students about failure and what to do to be successful."

Part of increasing the teachers' and, subsequently, their students' comfort with using fail words was that teachers normalized failure within the culture of engineering-in-the-classroom (40 percent interviewees) and provided context for fail words to ease students' minds (40 percent). The following statement from Tammy captures both of these ideas:

> Yeah, failure itself is never ... because I guess when you learn how to work with students you learn that certain words are what you make them to be. That's why I think I put the seven [for last year] where failure isn't a big deal. It just means you get to try again. I never really talked about it. Whereas now I make it a point to always talk about it. I almost need to put that up to a ten out of ten [for this year] because, like I said, it's part of our group norms when we have our small math group, the small reading groups, all the kids know the saying, "It's okay to fail." They know not only to say it but they know what it means. (Tammy)

Here, Tammy shares that she helps students understand the meaning of the word, failure, within the context of her instruction. Further, the use of fail words has become normalized in her classroom, routine and expected, rather than something that is weird or to be feared. Others alluded to this normalization as: "it was just a natural thing that happened [to use fail words]" (Cheryl); or "kind of taking the emotion out of it and just keeping it matter-of-fact" (Elissa).

Like Tammy, Joy described how she provided context for fail words. She discussed how in her third-grade classroom, she would "preface it [the word, failure] with why I'm describing it as a failure and how we can grow from that." She elaborated the ideal scenario:

> I think when I get the kids in the fall, they've been exposed to that word before and it's generally in a negative kind of way, even with video games or scores, just whatever the case may be. … I think as a teacher who's trying to develop classroom vibe and nurturing and caring, helpful to one another, I would actually have to have a class discussion, talk about the word, what I think it means, how I'm going to use it. That way, we

> start breaking the stereotypes of what it means to fail and really see it as a stepping stone to grow and become better. If I didn't do that, I think it might hurt kids' feelings. They might go home and talk to their parents about the word being used to describe something they did, and that could come back negatively on me, so I don't think I would just toss it out there without any kind of prefacing … Society I think has just placed too much of a negative association with the word. But in a sense I think it makes sense, but we've got to try to undo that, I feel. (Joy)

While she was careful to preface her discussions of failure, she saw the use of the word as "forc[ing] you to think, okay, we can't just be complacent with it [our design]. We can't just be content. We have to … exhaust all means … and fix it."

Both Crystal and Janet acknowledged that some of the context they provide around the use of fail words was to protect students in their classroom who may be inclined to take on failure identities. Crystal's students who had autism, for example, needed help understanding that design failure did not mean that the entire project was ruined. In all, 30 percent of interviewees—Crystal, Janet, and Diane—had a concern about students taking on failure identities if fail words were not used with care and packaged with careful context. In each of these cases, the concern was for those students who tended to struggle academically, including students with learning disabilities. About fail word use for such students, Diane offered: "Let them assess their own failure without calling it a failure, then underneath, [ask them to consider] what can we do to improve it. Let them assess that."

## Conclusion and Discussion

In this section, we first present an enhancement to the student/teacher failure response model introduced in the beginning of the paper. We then address the growth that we have observed in teachers' comfort with supporting students whose designs fail and in teachers' use of fail words, as well as growth in teachers' use of messages about failure into subject areas outside of engineering. Next, we share concluding thoughts regarding teachers' perceptions about how different students respond to design failure and fail words. We end this section by considering the power of mixed-methods research, and then turn toward implications of the study and future work.

### *A Broader Failure Response Model*

This mixed-methods study has reinforced and extended our past mixed-methods research on student responses to failure, teachers' responses to students whose designs have failed, and teachers use of fail words (Lottero-Perdue,

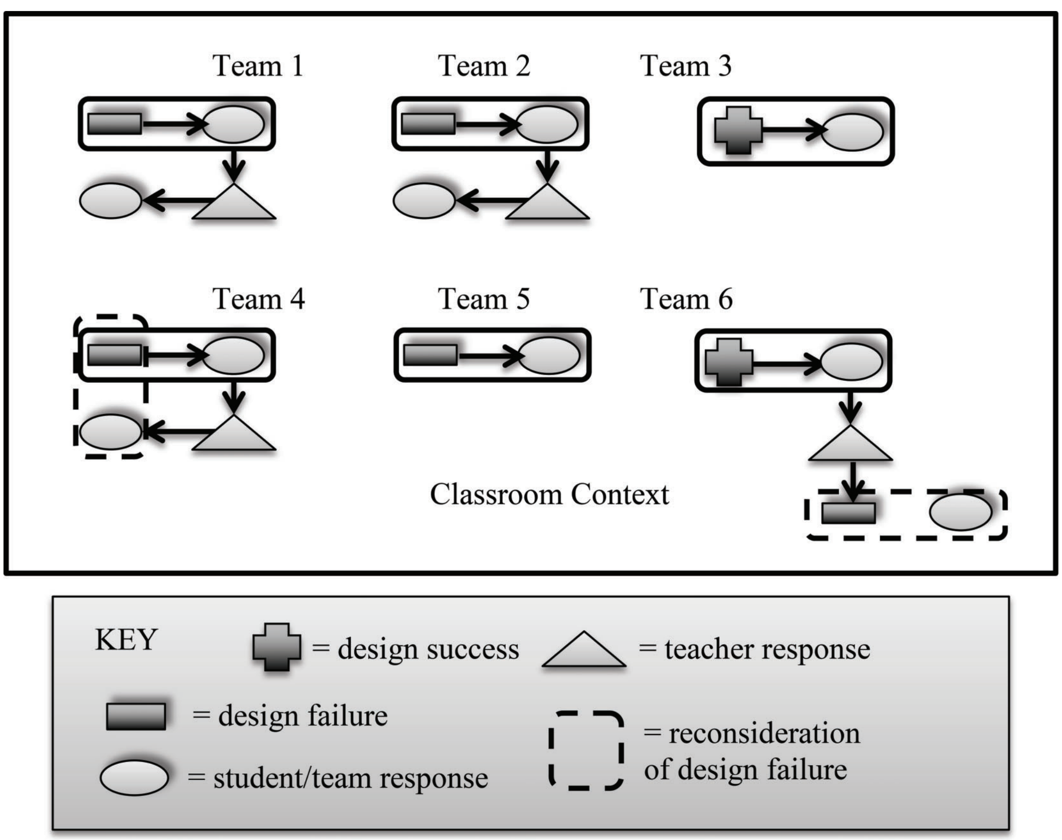


*Figure 7.* Classroom-based model of student/team responses to failure and teachers' responses to students/teams whose designs fail.

2015; Lottero-Perdue & Parry, 2014, 2015, this JPEER issue). Figure 7 is a classroom-based example that represents some of our learning from the present study. Near each one of the teams is a small symbol representing aspects of the earlier, simplified team-level model of student and teacher responses to design failure (Figure 1).

In Figure 7, six teams are depicted in a hypothetical classroom based on the range of student and teacher responses that we observed, and using our simple model of student and teacher responses to design failure. In this hypothetical classroom, each team has a slightly different experience with respect to design failure, and the teacher responds to teams in different ways:

Team 1: Design failure occurs. Team 1 understands how their design failed. The team has ideas about how to improve, but cannot agree on which approach to take. The team bickers, and the teacher intervenes to assist with peer dynamics. She suggests that they work together like a team of engineers. They begin to consider how to compromise.
Team 2: Design failure occurs. Team 2 understands how their design failed, but has no idea how to improve and is on the verge of giving up. The teacher reminds them that it's okay for their design to fail, and asks them to walk around the room to see what other teams are doing to get some ideas about how to improve, telling them to pay special attention to Team 5's design. They return to their team station with ideas for improvement.
Team 3: Design failure does not occur; all criteria are met. No need for teacher response to design failure.
Team 4: Design failure occurs. Team 4 does not understand why their design failed. The teacher asks probing questions to help students see why their design failed. Once she does that, the team is able to re-consider the design failure and generate ideas about how to improve.
Team 5: Design failure occurs. Team 5 engages in failure analysis and moves right into improvement. The teacher does not see a reason to intervene.
Team 6: The team thinks that their design is successful; however, it is clear to the teacher that the team did not test properly. The teacher intervenes, assisting the students as they re-test, and asserting that indeed, their design failed. Students then re-consider the results of the testing process, determining why failure occurred and how to improve.

It is entirely possible that Team 1 is unable to completely resolve their disputes, and not every team member is on board with the improvement plan, or that the improvements that students make do not necessarily result in a better design the second time around (or beyond).

Note that this classroom-based example captures many, but not all, of the ways in which students and teachers respond to design failures shared in the findings section. In addition to these specific team interactions, it is important to note that there is a larger "classroom context" in which the design successes and failures are occurring. It is in this space, represented simply by the rectangular boundary of the classroom, in which teachers can share and reinforce larger messages about design failure: that failure is an opportunity to learn and leads to better designs, that it's okay to fail, that failure is a normal part of the EDP, etc. This ideally creates a safe space in which design failure is more so a call to action than a tragic end point. These broader messages may take the form of a pre-emptive reminder prior to the testing process that it is entirely likely that many teams' designs will fail, and that this is a normal part of engineering. Students entering into the testing process with these messages in mind may be less inclined to express negative emotions or internalize design failures in a personal way. These messages can continue to be voiced to individual students, small groups, and the whole class throughout the EDP, and have the opportunity to impact all students—even those whose designs are successful.

### *Growth in Teachers and Across Subjects*

In this study, we have observed growth in the E4 EiE teachers in multiple respects. First, over the two years of their participation in the E4 Project, most teachers grew in their comfort with supporting students when their designs failed, and with using fail words during instruction. Further, they grew in the scope with which they applied the ideas of perseverance, resilience, and failure, often applying these ideas to other subject areas, or, if they had already promoted these ideas implicitly, making their application more explicit. This creates a sort of synthesis for elementary teachers who teach multiple subjects throughout the day in separate class periods, and perhaps more importantly, for the students they teach. The seemingly perennial question of students at any level is "when am I going to use this?" Although elementary students are typically taught all core content by a single teacher, the prevailing paradigm is to teach multiple single subject sessions throughout the day. In this setting, it is often hard for students to see the connections between what they are being taught in mathematics, science, English language arts, and social studies. This, in turn, can impact students' ability to synthesize what they are learning as they mature. Our initial findings on teachers applying what is learned in engineering design activities to other subjects suggest that further research on how engineering may serve as an effective platform for synthesis in all grade levels is needed.

### *Considering Different Student Groups*

One contribution that this study has made to our broader program of study on failure in elementary engineering education has to do with the way in which teachers perceive how different student groups will respond to design failure experiences. Teachers and some students were surprised when typically underperforming students persevered when faced with design failure and were able to devise smart designs. On the other hand, teachers were sometimes surprised when typically high achieving students—perhaps unaccustomed to truly being challenged when "the right answer" is neither apparent nor exists—were frustrated or inclined to give up when design failure occurred. We find this shift in the balance of power in the classroom to be interesting, and, as discussed below, a potentially fruitful future research direction.

This idea that struggling students may perform better than expected when faced with design failure may provide teachers with a sort of comfort when considering teaching engineering to all students. However, and as we have learned in each of our studies, some teachers worry that use of fail words students who struggle may cause or feed into existing failure identities. For similar reasons, teachers in our study who integrated fail words into their instruction did so with caution and care, providing context for what failure meant in engineering design, normalizing fail word use in the context of engineering, and using positive messages about learning from failure and perseverance during engineering instruction and beyond.

### *Mixed-Methods Research Program*

Our final conclusion is of the value of mixed-methods research in this study and across our entire program of research. We have been able to blend quantitative and qualitative findings in this study to make sense of teachers' reflections on failure after teaching engineering for two years. Video, interview, and survey data have informed our other work, enabling us to have a richer understanding of this complex aspect of engineering education: failure.

## Implications and Future Work

As a result of this work, we hope to introduce into the lexicon of engineering education the concept of *scaffolding students for failure*. More commonly in elementary school subjects, teachers consider how they can scaffold students for success. By scaffolding students for failure, we are referring to creating a safe, supportive environment in which students have the opportunity to learn from design failure experiences.

To be able to scaffold students for failure in engineering instruction, teachers should first be given a sort of figurative failure permission slip that says that it is okay for their students to generate designs that do not meet design criteria—or more bluntly—it's okay for their students to fail. Further, teachers who scaffold students for failure should have professional learning experiences or pre-service teacher education where they gain:

- access to curriculum, such as EiE, that includes the EDP and thus, provides opportunities for students to learn from failure and persevere in the face of setbacks;
- an understanding of how failure is a normal part of engineering and the EDP and can become normalized within the classroom setting;
- an awareness of the typical range of student responses to design failure; and
- a toolkit of *responses*—including general and specific interventions and the possibility of not intervening at all—that they can use when students' designs fail, and *messages* about design failure that they can share in broader classroom contexts.

We hesitate to add to this list: comfort with using fail words during engineering instruction. Indeed, we hope that teachers develop such a comfort, as we have seen among most of the teachers in the study. These teachers carefully introduced fail words and made their use normal in the context of engineering (and in some cases, beyond), reducing the fearful power that they have in other contexts. However, with continued concern that some student groups may become upset or identify as failures when fail words are used, we will stop short here in making a recommendation to use fail words or not until we have more data to address to this topic. We will recommend that if teachers use fail words, they do so with care, always associate failure with the design (not the student), and discuss with students what fail words mean in the context of engineering design.

When we reflect on this study, we are impressed with the growth and comfort that most teachers shared with regard to supporting students whose designs failed and using fail words. We wonder, however, about the extent to which teachers will continue to teach failure as part of the EDP and use fail words now that the E4 study has ended. It is our hope that students in E4 EiE teachers' future classrooms will continue to learn from design failure experiences, practicing their growth mindsets.

Our future work may involve additional video analysis in CIO site classrooms (from Year 2), the development of case studies that span both years of the E4 Project, and analyzing more of our student interview data for their perceptions about failure. Beyond the E4 Project, we are interested in investigating the seemingly flip-flopped balance of power in engineering design challenges when typically struggling students persevere and typically high achieving students are frustrated in the face of failure.

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## APPENDIX

### Interview Protocol

Note: This is a partial protocol, displaying those questions that were relevant to this study.

### Part A: Opening

[Interviewer shares: "Thank you for taking time for this interview out of your busy day. I appreciate your willingness to provide the E4 Project with your reflections beyond what you shared in the post-teaching survey."]

1. Can you reflect on how you felt about teaching engineering prior to participating in this project (before our 3-day initial PD in the summer of 2013)?
2. How do you feel about teaching engineering now? Do you feel more knowledgeable? More comfortable?

### Part B: General Reflections

3. On the final survey, you were asked how your implementation of the engineering lessons changed between last year and this year. You responded:

"…" [include participant's response here]
Can you talk further about that?

4. On the final survey, you were asked about any impacts—positive or negative—you have seen on your students, in general or for specific under-represented groups, as a result of their experiences with engineering activities in your class(es). You responded:

"…" [include participant's response here]
Can you talk further about that?

5. On the final survey, you were asked if you were surprised by any of your students' reactions to engineering. You responded:

"…" [include participant's response here]
Can you talk further about that?

### Part C: Overall Success of Students in Engineering Design Challenges

6. About how many teams did you have in your classroom? How many kids per team?
7. For each unit:

a. How would you describe a "successful ______ [include designed technology here]" within the engineering design process part of the ______ [EiE unit name] unit?
b. How many times did you allow students to redesign?
c. How many teams had a successful first design? Second? (Beyond?)
d. Did redesign enable more teams to be successful?

8. [Interviewer shares, "Another way to think about success is in terms of whether students, overall, have had a successful experience with engineering design as they engage in the entire engineering design process." And asks:]

a. What do you think it means for students to have, overall, a "successful engineering design experience"? [Teacher can answer broadly or with respect to a particular unit.]
b. How many teams would you say had such a successful engineering design experience, overall? In the ______ [EiE unit name] unit (ask for each unit taught)?

### Part D: Team/Student Reactions and Teacher Responses

9. Overall, how would you describe the range of student reactions when student teams did not succeed in their first designs? Follow up with:

a. Were any of these reactions surprising to you? If so, why?
b. How did these reactions compare to other occasions outside of engineering in which students do not achieve success in the classroom?

10. How would you summarize the different ways that you responded to students and teams whose designs were unsuccessful?
11. Can you share specific examples from one or both of your units in which a team's design was unsuccessful and you intervened?

a. How did those particular students respond?
b. How did you, in turn, respond to those students?
c. If the team was able to redesign after you intervened, was the team's next design more successful?

d. Do you have another example that stands out in your memory?

**Part E: Failure**

12. On the final survey, you were asked about how comfortable you were using the words fail or failure during instruction prior to participating in the project as compared to now. You shared:

"…" [include participant's response here]
Can you talk further about that?

13. On the final survey, you were asked to indicate the extent to which the EiE curriculum provided opportunities for students to learn from failure. You responded:

"…" [include participant's response here]
Can you talk further about that?

14. Did the way you supported your students' design successes and failures change between last year and this year? If so, how? Do you feel more comfortable supporting students' successes and failures now?

**Part F: Closing**

15. Do you have any other questions or concerns that you would like to share?

[Interviewer shares: "Thank you for participating in this interview! What you have shared will be helpful for our research team. I appreciate the time you have spent with me today."]