Board 90: Work in Progress: Response to Failure and Success in an ECE Course

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WIP - Response to Failure and Success in an ECE Course

Introduction

In engineering as a profession, failure is commonplace--attempted designs fail over and over as part of an iterative process in order to solve the problem at hand and meet desired specifications, experiments fail most of the time as hypothesis get tested, mathematical models have to be re-evaluated when solutions are not consistent or practical, etc. These types of failure are also part of the engineering education experience, along with the typical failures experienced in education in general--students do not achieve the scores they desire on homework, quizzes, and exams. Thus, the ability to navigate and respond to failure as an opportunity for growth and learning is a key component of the engineering enterprise. However, engineering education research is sparse on *how* students respond to failure.

Research on response to failure has been extensive in workplace settings, in which there is a very wide range of negative and positive responses to failure, which include emotional responses (denial, anger, bargaining, depression, acceptance, shock, fear, renewed dedication, increased susceptibility to stereotypes, blame, shame, despair, changes in interest, reassessing career, reassessing self-perceived ability) and cognitive and behavioral responses (working harder, working smarter, learning from failure). Thus, these responses may include combinations of emotional, cognitive, and behavioral responses. Research on responses to success likewise suggests positive emotions in response to success on work projects, such as pride, satisfaction, and happiness. In educational contexts, emotional responses to academic work have been found to be quite similar [1]. We use a portion of the Control-Value Theory of achievement emotions by Pekrun and colleagues to explain the range of emotions we observed after receiving exam scores. Whereas the cognitive and behavioral responses in educational contexts may more likely take the form of using better or worse study strategies such as spreading out study time vs. cramming, summarizing the big ideas of course vs. memorizing vocabulary terms.

Educational research on response to failure across different domains and ages--not just in engineering education--has been quite narrow because research has used theories that make very narrow predictions about response to failure, like self-belief theory[2], achievement goal orientation[3], expectancy-value theory[4], interest theory[5], intrinsic motivation theory[6], growth mindset theory[7], and so on. Educational research on response to success has been sparse, but also suggests positive emotions in response to success, but possibly a drop-off in adaptive study strategies after success (e.g., ‘resting on one’s laurels’). Although the education research on response to failure and success has been sparse, there has been quite a lot of broad work done on academic achievement. We expect that when we actually ask students about their

response to failure and success that students will respond in a way that incorporates aspects from multiple theories, but specifically from theories that focus more on this broad approach to academic achievement (e.g., achievement emotions). Therefore, in the present study we used multiple theoretical frameworks to guide our work but will specifically focus on the theory of achievement emotions[1] to guide our understanding of students' *emotional* responses to failure and success.

Our long-term goal is to find ways to help build resilience to failure and ways in which we can help students learn from failure (e.g., viewing failure as an opportunity), and hence it is critical to understand the range of responses to failure. Furthermore, to understand what response to failure looks like, we need to contrast it with response to success. Additionally, it is important to consider not only the standards of the course or the specific task (i.e., what counts as a failing score) but also the standards of the students. For instance, the same grade may be interpreted differently by two different students, one may see it as a success and the other may see it as a failure. Thus, it is critical to interview students to develop a better understanding of *their* response to *their* standard of failure or success.

For this work-in-progress, we address two questions: 1) What is the variety and frequency of students' responses to self-perceived failure and self-perceived success on graded exams, among undergraduate Electrical and Computer Engineering (ECE) Circuits students? and 2) What differences do we see in responses between students who self-identified as succeeding vs. self-identified as failing an exam? Towards this end, we gathered and investigated the full range of responses to failure from engineering students, specifically after the first and second exams of the semester in a second year ECE course at a large public university. This course is required for Electrical Engineering (EE) or Computer Engineering (CE) majors, so we believe that students see the course as important, and simultaneously put a great deal of grade pressure on themselves, making this an excellent test bed for measuring responses to failure and success in Engineering. The next steps will be to gather more interview data, develop a Likert-type questionnaire based on the coded interview responses, then gather data to generate evidence of reliability, validity, and fairness; and finally, to design and try out interventions.

Study Design

Our team is currently in the first-year phase of a three-year project and here we are reporting data from the first semester of the first year. In the first year, recruited engineering students consented and were asked to attend one initial interview and one follow-up interview if they felt they had done better or worse than expected on the first exam in the course. The initial interview was held at the end of September through the beginning of October, 2023, soon after receiving a grade on

the first course exam. Students were asked whether they did better/worse on that exam than they thought they would, their reactions to their score, study strategies, and planned changes after the first exam. Sample interview questions included “How did you react when you saw your exam score?” and “How and when did you study for the exam?”. The same students were then asked to participate in a follow-up interview after receiving a grade on the second course exam and this was at the end of October through the beginning of November of the same semester. In addition to selectively asking the same set of interview questions as the initial interview (this time with questions geared towards the second exam), the follow-up interview mainly focused on students’ actual changes regarding their study before the second exam. Interviewers mentioned students’ planned changes reported in the initial interview and asked whether students had followed their plans or had made any other changes. Importantly, all students who took exam 1 took the same exam and all students who took exam 2 took the same exam. The first exam covered the content from the first month of the course and the second exam covered content from the second month of the course.

Participants

We obtained approval from the university’s Institutional Review Board. Researchers entered the engineering classes to advertise the project and recruit participants. Reminders of recruitment were posted on the homework set and on Canvas as well. Prior to data collection, each participant completed a digital consent form. For the initial interview, a total of 27 engineering students aged 18 to 22 years participated, with 21 of those same students continuing to the follow-up interview that happened after their second exam. Table 1 displays the major demographic information for the 27 interviewees who provided demographic data.

Procedure

A total of 48 interviews were conducted by a team of five trained interviewers. All interviews were recorded and automatically transcribed using the Microsoft Teams platform, then checked for accuracy and to remove any identifying information. The initial interview was held between the end of September and the beginning of October, 2023, had a duration of around 20 minutes, and was followed by a brief motivation survey. The follow-up interview was shorter, lasting about 10 minutes, and was held between the end of October and the beginning of November, 2023. Participants received a $15 Amazon gift card for attending the initial interview and an additional $15 Amazon gift card if they participated in the follow-up interview. The original transcripts were cleaned by de-identifying specific information (e.g., course code or professor names) to protect confidentiality and anonymity. Two researchers independently developed a coding scheme and coded the cleaned transcripts, then engaged in discussions to reach an

agreement on coding, ensuring inter-rater reliability. Emotion codes came from the prior literature on academic achievement emotions and also from the transcripts (i.e., a hybrid approach). Study strategies codes were derived entirely from the transcripts (i.e., a bottom-up approach). After coding, each code was then given a count to represent the number of times that code was mentioned. For example, a person can express more than one emotion and may express the same emotion more than once during the interview. Thus, there could be more counts than participants. This is a standard method for doing counts in interviews[8].

Factor	Levels	N	%
Year in College			
	Sophomore	23	85.19%
	Junior	4	14.81%
Major			
	Computer Engineering	14	51.85%
	Electrical Engineering	10	37.04%
	Systems Engineering and Design	2	7.41%
	Simply Mentioned ECE	1	3.70%
Gender			
	Male	23	85.19%
	Female	4	14.81%
Race			
	Asian	13	48.15%
	White/Caucasian	10	37.04%
	Indian Subcontinent	5	18.52%
	Hispanic/Latino	1	3.70%
	Middle Eastern	1	3.70%

Table 1. Participant demographics. For *Race*, multiple options could be selected simultaneously.

Measures

A demographics form asked participants to self-report race, sex (with 4 options), year in school, college major, and parental education. The motivation survey--not discussed here--asked about interest, valuing of the course, perceived non-monetary costs of being in the course, self-efficacy, self-concept, mastery approach, and performance approach.

Data analyses

In addition to presenting descriptives on the coded interview segments, we also conducted chi square tests by emotions and study strategies codes by did-better vs. did-worse on each exam.

Results

On the first exam, 18 of the interviewed students felt they did worse than they had expected and 9 felt they did better; on the second exam the trend was reversed and 7 of the interviewed students felt they did worse and 14 felt they did better.

Positive emotions

Participants verbalized a wide range of positive emotions after exams 1 and 2, as expected from the general academic emotions literature, and far beyond what is predicted by other theories. The counts of emotions are shown in Table 2.

Exam 1	n		n		Exam 2	n		n
Positive		Negative			Positive		Negative	
Happy/Satisfied	18	Anxious/worried	27		Happy/Satisfied	11	Anxious/Worried	11
Confident	7	Sad	16		Confident	4	Sad	6
Relieved	3	Surprised	12					
		Overconfident	3					

Table 2: Count of emotions verbalized in interviews, positive and negative, after Exam 1 and after Exam 2. Only emotions with counts larger than 1 are shown.

Negative emotions

As with positive emotions, participants verbalized a wide range of negative emotions after exams 1 and 2, as expected from the general academic emotions literature, and also far beyond what is predicted by other theories. See Table 2 for counts.

Study strategies

Participants verbalized a wide range of study strategies used before exam 1, generally concerned with two areas: logistics (when, where, and with whom they studied) and materials they used (past semester exams provided as study aides to all students by course instructors, textbook, lecture slides, videos, etc.). See Table 3 for counts.

	Exam 1	Exam 2
Study strategy	number of mentions (rate per participant)	number of mentions (rate per participant)
Study past exams provided by instructor	**84 (3.11)**	**70 (3.33)**
Re-do homework	*32 (1.19)*	16 (0.76)
Study in advance	29 (1.07)	*32 (1.52)*
Write/review own notes	26 (0.96)	8 (0.38)
Study alone vs. with others	10 (0.37)	2 (0.10)
Attend review session	12 (0.44)	0 (0.00)
Review lecture slides	11 (0.41)	4 (0.19)
Attend office hours	11 (0.41)	16 (0.76)
Attend/view lecture	11 (0.41)	9 (0.43)
Review textbook	11 (0.41)	9 (0.43)
Use Internet resources	9 (0.33)	2 (0.10)
Attend tutoring	3 (0.11)	0 (0.00)

Table 3: Count and rate of study strategy use in preparation for Exam 1 and Exam 2. Strategies are sorted by frequency of use to prepare for Exam 1; in both columns, the most frequent strategy is shown in **bold**, 2nd most frequent in *Italics*, and 3rd most frequent is underlined.

Comparisons between those who did better versus those who did worse

All observed counts and full results of chi square tests are shown in Table 4. For exam 1, a one-way chi squared test showed that students who did better verbalized significantly more positive emotions than students who did worse than expected (omega = 0.62). However, there was no significant difference on negative emotions (omega = 0.02).

For exam 1, chi squared tests on study strategies showed no disproportions between those who said they did better and those who said they did worse (see Table 4 for results).

For exam 2, chi squared tests on emotions showed no disproportions for negative (omega = 0.12) nor positive (omega = 0.28) emotions for those who said they did better or worse on exam 2.

For exam 2, chi squared tests on study strategies showed no significant disproportion between those who said they did better and those who said they did worse. A number of students commented on the different nature of the second exam--drawing more on new content from this course and less on reviewed content from the prerequisite course.

Discussion

In the present study we conducted interviews with undergraduate ECE students to better understand their responses to self-perceived failure and self-perceived success on graded exams. For the purposes of this paper, we focused on two categories of responses: their emotional responses and their reported study strategies (i.e., their cognitive and behavioral responses). The interviews with ECE students revealed that students do in fact have varied responses to self-perceived failure and success on graded exams. In general, our findings are consistent with the academic achievement motivation literature: success leads to more positive emotions[4]. However, our results add important nuance that likely would have been missed if we had only focused on one theory to guide our questions and interpretations. For example, according to Carol Dweck's self-belief theory, students who believe they cannot become more able in a domain (they hold fixed or entity self-beliefs) will respond to failure by believing they have low ability and that nothing will help them succeed[2]. Applying this theory would lead a researcher

	Observed counts of did-better students	**Observed counts of did-worse students**	**Chi-square (*df* =1)**	***p***	**Cohen's omega**
Exam 1					
Emotions					
Negative Emotions	21	44	0.03	0.86	0.02
Positive Emotions	20	12	12.25	< 0.05	0.62
Study Strategies Used Study from…					
Past exams provided by instructor	27	57	0.05	0.82	0.03
Number of days before to prepare	14	15	2.91	0.09	0.32
Homework	12	20	0.25	0.62	0.09
Slides	4	7	0.05	0.83	0.06
Study Strategies Planned Plan to study from…					
Past exams provided by instructor	7	10	0.47	0.49	0.17
Number of days before to prepare	3	8	0.18	0.67	0.13
Textbook	2	2	0.50	0.48	0.35
Exam 2					
Emotions					
Negative Emotions	11	7	0.25	0.62	0.12
Positive Emotions	12	3	1.20	0.27	0.28
Study Strategies Used Study from…					
Past exams provided by instructor	48	22	0.11	0.74	0.04
Number of days before to prepare	21	11	0.02	0.90	0.02
Homework	12	4	0.50	0.48	0.18
Office Hours	13	3	1.53	0.22	0.31
Study Strategies Planned Plan to study from…					
Past exams	6	2	0.25	0.62	0.18
Number of days before to prepare	6	4	0.20	0.65	0.14

Table 4: All observed counts and full results of chi square tests.

to measure entity beliefs and ability beliefs only, and to intervene only on the entity beliefs. However, we found that students, regardless of whether they thought they did better or worse, discussed study strategies that they could implement to perform better on the next exam. Thus, regardless of whether or not a student may hold a fixed or entity self-belief they were still likely to report a strategy that they may use or change for the next exam. We further discuss this below.

When we examine differences in responses between students who self-identified as succeeding compared to self-identified as failing an exam, we found one significant difference. We found that students who reported doing better than expected on the first exam also reported significantly more positive emotions than those who reported doing worse. This finding is well-supported by academic achievement motivation theories[1][4]. However, what is missing from the literature is the comparison of students who thought they did better to students who thought they did worse than expected. Although students who did better reported more positive emotions, students who did worse than expected *also* reported positive emotions, mainly feeling confident or experiencing hope during exam 1. This finding makes sense when we consider the motivation literature in that if a student is feeling confident or hopeful during an exam they may expect a certain grade and if they do not receive that grade they are then likely to report doing worse than they had expected[1]. To further illustrate this, although not significantly different, we found that students who reported doing worse than expected on exam 1 also frequently discussed being surprised by their grade for exam 1. Overall, the interviews with students provided us with a range of positive and negative emotions that students experienced both during and after the two exams. Further, the fact that we only found one significant difference in terms of the range of emotions that students who did better compared to did worse mentioned is novel. The current pattern of results suggests that students, regardless of how they did, may report similar emotions; however, the specific context in which those emotions are elicited should be further investigated. Therefore, these findings are novel because the use of interview techniques after receiving scores on an exam is a method that has not been used in the education literature to date. Our results demonstrate the important insights that interviews can provide when considering how students respond to their test scores.

Our interviews revealed that students, regardless of how they thought they did, mentioned using several strategies. The use of various study strategies is well-supported by the self-regulation literature[9]. However, the interviews provided insights into the differing levels of processing, such as deep or shallow processing[10], that students engaged in when using specific strategies. Specifically, the pattern of results reported in Table 4 helps provide insights into the types of study strategies that may be more or less effective for this ECE course. For example, although there was not a significant difference, students who self-reported as succeeding most commonly reported using past exams and giving themselves time to study before the exam. Thus, it seems that these two strategies, if used correctly, may be particularly helpful in terms of preparing for exams in ECE courses. Although students who self-reported as failing on exam 1 and/or exam 2 also mentioned using previous exams provided by their instructor as a study strategy it is important to consider that there likely are differences in terms of *how* these previous exams were

used. For example, during one interview a student who perceived themself as failing the first exam mentioned using the previous exams as a study strategy in which they went over problems and looked up the solutions when stuck. Conversely, a student who perceived themself as succeeding on the first exam also mentioned using the previous exams as a study strategy but specifically mentioned that they treated these previous exams as a real test. That is, they thoroughly wrote out each step when solving a problem and gave themself the same amount of time they would have during the exam. Therefore, even though these two groups of students both mentioned using previous exams as a study strategy, the former student seems to have engaged in more shallow processing compared to the student who treated the practice exam like an actual exam.

Limitations

It is important to note a few limitations of the present study. The first is that our sample size is relatively small because we have the same students complete both interviews and we limit our data collection window to help prevent recall bias. However, we have conducted interviews with 28 additional participants after their first exam in the Spring 2024 semester. We are currently conducting interviews with these participants after their second exam and will report the results with these additional data during the conference. Although this sample size may limit our generalizability, it is important to note that our goal is not necessarily to generalize, but rather to develop a baseline understanding that can be used to develop materials that we can further test to ensure they can then generalize to other EE or CE courses. Another limitation is the possibility of recall bias. Although we made decisions in terms of data collection to limit the potential of this, it is still possible because students are asked to think about things they did before the exam and immediately after the exam. There is also the possibility of a social desirability bias, particularly among students who did worse, which may have contributed to our non-significant differences. Although there are limitations in using self-report methods, collecting objective and in-the-moment data around student study strategies and emotions is prohibitive for several reasons. The first is that it would require observing students studying before the exam, which would be time consuming and also potentially lead to social desirability bias. The other is that measuring emotions through observations can lead to inaccuracies as people experience and express emotions differently. Therefore, even though there can be bias when using self-report methods, it was the most appropriate way to measure study strategies used and the emotions students experienced in the present study.

Future Directions

Currently, in this project we adopted mixed-methods approaches (qualitative plus quantitative approaches) in our first year of data collection with a proposed three-year timeline. The first year's work focuses on interviewing engineering students to understand their responses to success and failure in ECE course exams. We are currently collecting additional interview data during the Spring 2024 semester and will re-analyze the results with this additional data. Building upon the findings of year one, a preliminary questionnaire will be generated to assess engineering students' responses to success and failure on graded exams. In year two, psychometric properties of this questionnaire will be examined to ensure the questionnaire's reliability, validity, and fairness. Interventions targeting students' responses to failure will be developed in year three, informed by year two's results.

Conclusion

Overall, in the present study we sought to explore the variety and frequency of students' responses to self-perceived failure and success on graded exams in an undergraduate ECE course and whether there are any differences among these students. To do this, we specifically examined the emotional responses students may have after their exam as well as the study strategies they used to prepare for the exam. Our results demonstrate that undergraduate ECE students who perceive themselves as failing or succeeding on an exam have a range of positive and negative emotions. However, students who perceived themselves as succeeding on the exam were more likely to discuss feeling positive emotions when they received their grade compared to students who perceived themselves as failing. We also found that students reported using several different study strategies regardless of whether they perceived they failed or succeeded on the exam. However, our interviews shed light on the fact that students who did better or worse may have been engaging in similar strategies but using them differently. That is, students who did better discussed using more deep-level processing when using a study strategy compared to students who did worse. This work-in-progress provides an important first step in terms of understanding the wide range of responses students may have when they perceive success versus failure.

References

[1] Pekrun, R., Goetz, T., Frenzel, A. C., Barchfeld, P., & Perry, R. P. (2011). Measuring emotions in students' learning and performance: The Achievement Emotions Questionnaire (AEQ). *Contemporary Educational Psychology*, *36*(1), 36-48.

[2] Dweck, C. S. (2000). Self-theories: Their role in motivation, personality, and development. Psychology Press.

[3] Elliot, A. J., & McGregor, H. A. (2001). A 2× 2 achievement goal framework. *Journal of Personality and Social Psychology*, *80*(3), 501-519.

[4] Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology*, *25*(1), 68-81.

[5] Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, *41*(2), 111-127.

[6] E.L. Deci and R.M. Ryan. 2012. Self-determination theory. In Handbook of theories of social psychology, P.A.M. van Lange, A.W. Kruglanski, and E.T. Higgins (Eds.). Sage Publications Ltd., 416–436.

[7] C.S. Dweck. 2006. Mindset: The new psychology of success. New York: Random House.

[8] Chang, Y., Voils, C. I., Sandelowski, M., Hasselblad, V., & Crandell, J. L. (2009). Transforming verbal counts in reports of qualitative descriptive studies into numbers. Western journal of nursing research, 31(7), 837-852.

[9] Zimmerman, B. J., & Pons, M. M. (1986). Development of a structured interview for assessing student use of self-regulated learning strategies. *American Educational Research Journal*, *23*(4), 614-628.

[10] Greene, B. A. (2015). Measuring cognitive engagement with self-report scales: Reflections from over 20 years of research. *Educational Psychologist*, *50*(1), 14-30.