What is Failure? A Qualitative Study of Engineering Students' Definitions of Failure

David Zabner, Tufts University
Mr. Spencer Johnathan Sabatino, Cornell University

Spencer Sabatino is a PhD candidate at the Robert Frederick Smith School of Chemical and Biomolecular Engineering at Cornell University. Spencer's research interests include studying engineering students' beliefs and their effects on broader student outcomes. He earned his Bachelor of Science degree in Chemical Engineering and his Master of Science in Chemical and Biomedical Engineering from Miami University in 2022.

Dr. Herman Ronald Clements III, University of Nebraska - Lincoln
Trevion S Henderson, Tufts University

Trevion Henderson is Assistant Professor of Mechanical Engineering at Tufts University. He earned his Ph.D. in Higher Education at the University of Michigan.

Dr. Allison Godwin, Cornell University

Allison Godwin, Ph.D. is the Dr. G. Stephen Irwin '67, '68 Professor in Engineering Education Research in the Robert Frederick Smith School of Chemical and Biomolecular Engineering at Cornell University. She is also the Associate Director of the Cornell NanoScale Science and Technology Facility and a McCormick Teaching Excellence Institute Research Fellow. Her research focuses on how identity, among other affective factors, influences diverse groups of students to choose engineering and persist in engineering. She also studies how different experiences within the practice and culture of engineering foster or hinder belonging, motivation, and identity development. Dr. Godwin graduated from Clemson University with a B.S. in Chemical Engineering and Ph.D. in Engineering and Science Education. Her research earned her a National Science Foundation CAREER Award focused on characterizing latent diversity, which includes diverse attitudes, mindsets, and approaches to learning to understand engineering students' identity development. She has won several awards for her research including the 2021 Chemical Engineering Education William H. Corcoran Award, 2022 American Educational Research Association Education in the Professions (Division I) 2021-2022 Outstanding Research Publication Award, and the 2023 AIChE Excellence in Engineering Education Research Award.

Katherine Becking, Cornell University

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Abstract

This full empirical research paper investigates students' definitions of failure or struggle in order to create a more student-centered approach to learning. Failure or struggle is an important part of the learning process. However, formal engineering education structures have historically stigmatized failure. Students are expected to "get it" on a prescribed term schedule, high-stakes assessments are the norm, and engineering culture positions efficiency and smartness as primary. Prior work has shown that when failure is intentionally included in classroom experiences, students have deeper learning. However, in prior work, the definitions of failure have been framed by the researchers. An understanding of students' experiences and definitions of failure and their impacts on students' developing identities as engineers can shape how failure is operationalized in classrooms, and even create opportunities for personalization of failure experiences. In this paper, we examine existing literature definitions of failure and students' definitions of failure to provide a more robust and participatory framing of this phenomenon. The paper proceeds in three parts. First, we review extant literature defining failure and its manifestations in engineering education contexts to establish a conceptual framework for our study of failure among engineering students. Second, we describe the qualitative component of a mixed-methods study in which we longitudinally interviewed 11 students at two private universities in the Northeast in Spring 2025 about their definitions of and experiences with failure in undergraduate engineering education. Finally, we synthesize these results to propose a conceptual framework for meaningful failure—framing failure as a positive part of learning to support students in taking academic risks, embrace uncertainty, and learn from setbacks to ultimately achieve success connected to who they are. Our results reveal three categories of experiences that vary in their alignment with current literature-based definitions of failure: Category 1) Those that the literature would define as failure, but which engineering students would not; Category 2) those that both literature and engineering students recognize as failure, and Category 3) those that literature would not define as failure, but which students would. These results provide opportunities for reframing how failure is defined in research and engaged with in curricular design to support opportunities for supported failure that is connected to students' experiences and understandings.

Introduction

Failure is a common experience in engineering education and manifests in different ways for different people. To some, failing is giving up on a task [1], or not meeting an expectation, whether academic, such as grades [2], or design-based, such as a product design not meeting standards [3]. Despite how frequently failure comes up in educational contexts, it is heavily stigmatized. To many students, failure induces feelings of depression, shame, and embarrassment [2], [4], [5], [6], [7], [8] and lowers willingness to take risks in academic contexts [9]. This

negative framing perpetuates an overarching stigma around failure, causing students and faculty to actively avoid failure in classroom settings.

Although much literature highlights how failure can promote negative outcomes for students, learning sciences research has also examined how failure can be used to enhance student learning. Initial work on impasse learning [10] and productive failure (PF) [11], [12], [13] demonstrated how failure can create awareness of the gap between what a student knows and the key concepts being taught, which in turn, promotes retention of information, transfer of knowledge to new contexts or situations, and stronger engagement of prior knowledge when solving problems in various STEM disciplines. The productive failure approach, in particular, has been repeatedly shown to outperform direct instruction in classrooms, including when active learning follows direct instruction [13], [14], and is therefore a strong model for effectively designing for failure in the classroom. While the PF definition of failure is useful for understanding student learning, how people define and experience failure varies widely [15], [16], and students' definitions and experiences may not align with how failure is framed by proponents of a PF approach.

A discrepancy between students' definitions of failure and the definition from Kapur's PF framework may create situations where 1) students experience failure according to the PF framework, but not according to their own definitions, 2) students experience failure that is also defined as failure by the PF framework, and 3) students do not experience failure according to PF but do personally feel as if they are experiencing failure. In Category 1, the learner may get all the benefits of a productive failure experience without the documented negative outcomes, and in Category 3, the opposite may occur.

Literature Review of Failure Definitions

Failure is a complex phenomenon and has been studied, framed, defined, and experienced in numerous ways in varying contexts in education. Prior studies in STEM education have provided overviews of commonly described failure definitions from instructors and professionals, with some discussion of student definitions [15], [16], [17].

We began this research with a "process-oriented" definition of failure [11], [18], drawn from a PF framing. In the PF framework, failure is described as an important part of a learning process within which students iterate on complex, ill-structured problems, generating potential solutions based on prior knowledge of related topics and can be detected through moment-to-moment emotional and physiological responses [19], [20]. For example, under this definition, failure occurs when students reach an impasse in problem-solving and can no longer continue [10], [11].

Complementing this process-oriented definition, we also integrate an "outcome-oriented" perspective of failure [6]. Outcome-oriented definitions of failure describe the gap between an expected or desired outcome and the realized outcome [21]. For example, a prototype that does not meet the requirements of a design project would constitute a failure, even if iteration could correct the issues. This interpretation contrasts with other perspectives that equate failure as only complete disengagement or abandonment of effort [22].

Prior work also distinguishes between failure and errors [23]. Errors often occur during learning

tasks; however, they can often be quickly corrected without preventing goal achievement. Failure, by contrast, involves halting forward progress towards achieving the intended goal. Discussion of failure often uses longer-term measurements related to student outcomes on a particular task [24]. In this work, we juxtapose Kapur's process-oriented definition of failure and our participants' definitions of failure.

Study Purpose and Research Questions

Examining the definitions of failure used by students and the PF framework may be a first step in understanding students' failure experiences as falling into 3 different categories. These categories may arise from the overlap between the definitions of failure given by students and prior literature. These categories may be useful to personalize and improve PF as a pedagogical approach. This work explores how students define and experience failure in engineering education by answering the following research questions:

RQ1: How do students typically define failure in engineering education?
RQ2: How do students' definitions of failure overlap with, and differ from, prior theoretical framings of failure?

Methods

This study is part of a larger multi-year, multi-institution project exploring the potential applications of failure-based learning to the personalization of learning in undergraduate engineering courses [25]. The data for this paper come from the project's classroom-level learning environments strand during the Spring 2025 term, which used a concurrent mixed-methods approach to gather pre-/post- surveys, observations, critical event interviews and surveys, and beginning- and end-of-term interviews [26]. Our participants for the Spring 2025 semester were first- and second-year students in required engineering courses at two private R1 universities in the Northeast. At University 1, participants were sampled from an introductory mechanical engineering course open to all engineering students. At the University 2, participants were sampled from a required introductory programming course offered by the engineering department for engineers.

At the beginning of the semester, we distributed a survey measuring various factors related to student failure responses, such as engineering role identity [27], fear of failure [6], and goal orientation [28], [29]. We used the survey responses to perform maximum variation sampling across backgrounds and psychosocial constructs measured to maximize student experiences and definitions of failure [30], [31]. We conducted semi-structured interviews with 11 participants (see Table 1) at the beginning of our study and at the end of the academic term, lasting roughly one hour each, with all but one of the 11 participants–Rachel only participated in the end-of-term interview. The beginning-of-term (BOT) interview focused on the participant's past experiences in engineering, the salience of their engineering role identity, and how the student responds to and experiences failure, as well as exploring the participant's personal definition of failure and how they perceive others in their life as defining failure. The end-of-term (EOT) interview centered on the participant's moments of failure throughout the semester and the impact of specific aspects of the course's structure on their failure experiences. For this work, we only analyzed data from the

BOT and EOT interviews. While we analyzed data from many parts of the two interviews, the majority of the quotes discussed in this work were responses to the question: "We know that people think about what constitutes failure or success differently. How do you define failure?"

We transcribed and then coded the interviews in two phases. We first used in-vivo coding to identify key perspectives on failure in participants' own words to preserve their unique definitions and experiences described in the interviews [32]. We then used axial coding to categorize in-vivo quotes, focusing on how participants define and experience failure in engineering. The research team met regularly to ensure agreement about the meaning of each axial code and developed a codebook to record these definitions. In this work, we explore codes under the parent code "Failure Definitions" and its subcodes (see Table A1 in the Appendix). Other axial codes included student definitions of success, student responses to failure, identity, perspectives on course structure, and sources of emotional support for participants.

Table 1: Participant list and demographic information for semi-structured interviews

Pseudonyms	**Demographic Information**	**University**
Liam	Latino Man	1
Jessie	White Woman	1
Jet	Asian Man	1
Gabriel	Latiné Person	1
Alex	White Woman	1
Harper	Asian Man	1
Ghana	Black Man	1
Felix	Asian Man	1
Jasmine	White Woman	2
Georgia	White Trans Woman	2
Rachel	Latina Woman	2

Results

RQ1: How do students typically define failure in engineering education?

Across the participants, we found four key factors that participants use to ground how they interpret an experience as a failure or success in engineering.

Students focus on grades

Participants frequently told us that they relied on external metrics, particularly grades, to define failure. We found that some participants use grades, particularly final grades in a course or GPA, as an objective benchmark of whether they failed or succeeded, regardless of context. Participants' opinions varied about what type of grade marked an experience as a success or failure. For example, some participants used letter grades to categorize academic experiences as successful or failures, as Jet highlighted:

> I don't want to just have an A at the end of the year. I want to make sure that... I want to get an A on this first prelim. I want to get [an] A on the second one and an A on the final, and I think that's representative of my perception of a high achiever.

Jet discussed his standards as A's for his exams and courses, and any deviation from that goal was a failure. Jet also tied his grades to his sense of self as a high achiever. Participants who discussed grades as being integral to their understanding of failure also connected this definition to other outcomes. Gabriel, for example, connected getting an F to having to retake courses, and Liam explained that having a high GPA was critical to his long-term goals of getting an internship and a job.

Other participants used a relative comparison to peers when discussing grades as a definition of failure. These participants leveraged comparative statistics on exams or assignments, or had discussions comparing their grades with friends and classmates:

> A lot of times, especially where there's a benchmark, it's kind of externally communicated, but I often set my own [expectation], like "Okay, what is the average? I do want to do better than the average." - Harper

> So, I think the first thing I do [after a possible failure moment] is I look up how big of a deal this result is. If it's a bad prelim score, I might wait to see the median or talk to my friends to see how bad this grade is. So I say, that's the first thing I do. - Alex

Harper and Alex relied on benchmarking within their contexts to gauge their success or failure. Other participants, such as Jet and Alex, provided further discussion of how they used particular friends they perceived as typically successful to define failure on assignments:

> I talked to one friend who was in the class with me. And I wouldn't say it was a helpful interaction, but it kind of like put me into perspective knowing that this actually was a bad grade, because that friend did, like, significantly better than me, and I knew that... I knew that, like, I could do just as well but I really underperformed. And it kind of just emphasized what was on [grading software] versus what was like in front of me. - Jet

> We all put in approximately the same amount of effort, and if I score average between my friends, I feel great. - Alex

These examples demonstrate the numerous ways in which participants used grades relative to academic performance to define failure.

Personal expectations matter more than the expectations of others

Participants frequently defined failure in terms of their expectations for themselves. For example, Ghana highlighted the effect of these expectations on his failure definitions:

> Failure is like when I didn't put in as much effort as I should have, and therefore didn't get everything I wanted out of it... It's about my effort level, you know, I think if I put in X amount of effort, I think it's completely viable to get X amount out of it.

> But if I only put in, you know, half or a quarter or a third of as much effort as I could have, you know, only 30%, 20%, 50%...it's just not good enough for me.

Ghana's definition was governed heavily by internal expectations of himself, influenced by his prior experiences, such as previous grades or perceptions of ability and effort in the context of the assessment. For Ghana, failure was his lack of effort or exertion for a particular assessment. Liam described similar experiences:

> And, I think after the first semester, and after having a pretty good performance on the first semester, I sort of set the standards a little bit more concretely and a little bit higher after seeing like, "Okay, I can do, I can do this, and I can do it to a certain degree. - Liam

Liam used prior performance to set expectations for his success and defined not meeting those personal expectations as failure. Both of these participants contrasted their personal expectations with the expectations of meaningful others in their lives, such as their parents, highlighting how their definition of failure was internally driven versus an externally set explicit expectation. They also both discussed how their backgrounds as second-generation immigrants influenced their desire to "get the most out" of their education and saw learning as a process for their future versus a performance-oriented outcome.

> I think my standards of success or failure are often motivated by… I feel like I have to just make the most out of this opportunity, because of the fact that I think my background just makes me realize that it truly is a privilege to be here. And being here and not making the most out of it, and not pushing myself as much as I can, is sort of wasteful and not acknowledging the effort that has gone into me being able to be here. - Liam

> I feel like I put, like, a little more pressure on myself, you know, because I guess my father, you know, fought so hard to come here and, you know, kind of like, give himself and give us and his family in general, like the best opportunities ever could. I feel like I try to make sure that he didn't, you know, just waste that on me. - Ghana

With these participants we see that their failure definitions are deeply internal and are not based on pressure from their parents, who they describe as supportive rather than demanding.

Students consider effects of failures on long-term plans

Many participants discussed how their failure definitions accounted for the magnitude of the failure moment on their future opportunities. While some participants acknowledge smaller events as failures, such as low assignment grades, they distinguished these failure moments from failure moments that potentially had long-lasting impacts on their academic or professional careers.

> I'd say when I've really failed is when I had a setback and I wasn't able to pick myself up again. So, let's say I got below median on the chem test. Failure for me would be if I let that setback affect my entire college grade, like to me, that would be failure. - Alex

> A true failure would be something that I will remember in a month or two, something like an exam grade that is so low that it's going to seriously affect my course progress, or not getting on a project team and it's going to affect my course selection for next year - Gabriel

Both Gabriel and Alex acknowledged that smaller failures may occur, but the most significant form of failure was when something might compromise their long-term plans. These participants projected the failure moment onto future events, such as graduation or internship and job prospects, when describing their definitions of failure. At the end of the semester, Gabriel recounted almost failing a math course and why he viewed it as a failure:

> And then after I finished the exam, then I was very, very stressed because I didn't know if I had passed the course, and I was concerned that this would affect my ability to affiliate [with engineering], and I'm also on track to graduate early, and I didn't think that this was going to affect my ability to graduate early because I would still be under the credit limit if I just added this course for the next semester. But I really didn't want to do that… the feeling was like all of the work and effort that I put into the course so far wouldn't have counted for anything.

Gabriel reflected on how the possibility of failing his math course registered as a failure for him purely because of how it would affect his ability to affiliate with his engineering major on his early graduation timeline, potentially affecting his long-term plans to join engineering even if it did not affect his ability to graduate. He also discussed that failing the course would increase his workload for the next semester, and that the additional workload would be a significant implication of his failure. The temporal aspect of the effects of failure emerged from these interviews as an important part of students' definitions of failure.

Context matters for some students

Participants also contextualized their efforts and outcomes based on perceived course or activity difficulty, personal relevance, competing goals, and contextual factors (such as illness, effort expended, activity difficulty, or credit load):

> I got a B, I got a C, I got an A, you know, to me, as long as it was a pass and I know I gave in all my effort, then I'm still happy, you know, but if I failed and I gave in all my effort, I'm, you know, definitely still very upset. And might take me, like, a little while to, you know, move on from that. But, um, you know, I kind of believe that it's all about, you know, keeping going. - Ghana

> If I studied a lot for a test, and let's say I got an 80, I'd be really disappointed in myself. But if I didn't study at all for the test, haven't been to the last 10 lectures and got an 80%, I'd be ecstatic. So, I guess it's based on the amount of effort I put in. - Alex

> I try to set realistic expectations or standards. I think realistic is definitely sort of a loose word, but within that, I think I try to encompass my ability level and also perceptions of where I should be and how I should be performing for stuff like maintaining a GPA so that I can apply to internships next summer…I can look at

> something and be like, "Okay, well, I want to have a certain performance in this class. And you know, if I know it's a very difficult class, then maybe that standard is lowered a little bit in comparison to a class that would be comparably easier, but also the standard... I try to not set it outside of a reasonable range of what I could be doing. I'm not going to be like, "Oh yeah. I want to get a 105% in a class that doesn't even offer extra credit." - Liam

Several students in our study shared situational standards for success depending on the context of their term, course, or activity. Unlike students who adopted static/objective definitions such as letter grades or GPA goals, these students turned to a combination of internal and external criteria to judge their experiences.

Discussion

This qualitative study explores how students define and describe failure in order to engage these considerations alongside current theoretical definitions from literature. Our analysis demonstrates several important considerations in students' definitions of failure, including variation in external standards, how background and goals shape student perceptions, and the temporal and contextual considerations some students make in defining failure. We use our findings to explore 3 categories of failure-experiences: Category 1) experiences that the literature would view as failure, but which the students would not; Category 2) those that both literature and engineering students recognize as failure, and Category 3) those that literature would not define as failure, but which students would.

RQ2: How do student definitions of failure overlap with prior theoretical framings of failure?

A high-level outcome of this research is that participants' definitions of failure vary–some are process-oriented, and account for temporal and contextual factors, and some are outcome-oriented, which may include absolute external standards or relative comparisons to peers. We found that students' discussions of failure were always on a larger scale than the discussions in the literature from either a process- or outcome-oriented perspective. Students focused on the outcomes of high-stakes assessments, final course grades, cumulative GPA, and even degree and career progression as indicators of failure. This framing stands in contrast to learning sciences definitions that focus on in-the-moment impasses. Existing definitions of failure, whether process- or outcome-oriented, most often focus on failure at relatively small scales (e.g., at the scale of particular exam problems, assessments, or singular design decisions). This difference in definition could prove to be a challenge for future student-facing interventions and discussions about failure. Future qualitative work must acknowledge or bridge the gap between students' definitions of failure and those used in the literature, which may include providing participants with a definition of failure, changing the definition to match students' beliefs, or exploring why and how participants' espoused definitions do not match psychological signals that occur in moment-to-moment studies within the reality in the classroom [19]. There is an opportunity to better operationalize failure by including different temporal and contextual factors in measurement that emerged from this study.

This study is one of the first steps in identifying mechanisms for how students individually

experience and interpret failure to develop appropriate measurement and interventions to personalize engineering learning. In working to understand how students' definitions and experiences may differ from the current theoretical framings within the literature, there is an opportunity to leverage the positive aspects of failure in student learning while avoiding negative cognitive and emotional responses, also associated with the phenomenon that often result in maladaptive behavior responses. Students who discuss failure purely from the perspective of grades, such as Felix and Harper, had definitions more aligned with the outcome-oriented definitions of failure than the process-oriented definitions of failure [13]. For these students, process-oriented failure experiences, as defined by prior literature, may have negligible deleterious effects (i.e., this experience will fall into Category 1) if the failure experience doesn't prevent a positive outcome, such as a high grade. We draw a similar conclusion for students whose failure definitions are focused on events and actions that negatively affect their long-term success and goals, such as Gabriel. Students like Gabriel viewed failure not purely as a single, isolated event or outcome, but rather a disruption of a process to achieving long-term goals (e.g., finding an internship or a job). For a student like Gabriel, we would classify becoming stuck on an ungraded in-class exercise as a Category 1 failure. While Kapur would call this a failure, Gabriel would not likely see that moment alone as disrupting the achievement of his long-term goals. Conversely, a social faux pas risking Gabriel's chances for an internship might be a Category 3 failure since it presents none of the affordances of failure that Kapur describes but may register as an important failure moment for Gabriel.

Students whose failure definitions were grounded in internal expectations, such as Liam and Ghana, may not hold precise, measurable definitions of failure. For example, Ghana used his own effort to gauge whether an experience was a failure. Effort, in this sense, is not externally measured, but rather a perception of effort invested. Similarly, Liam's framing of failure was rooted in prior experiences and expectations, which provided flexibility to define failure based on context. Both Liam and Ghana discussed how, despite their high standards for themselves, their definitions of failure meant that failure was a result of shortcomings in their own effort rather than the inability to do the work or ultimately succeed. This framing shifts the discussion away from both the theoretical definitions of process- or outcome-oriented failure and moves toward considerations that balance both cost, value, and expectations more consistent with Expectancy-Value Motivation Theory [33], [34]. Because of this divergence from existing framings of failure, even in scenarios where these students experience a process-oriented failure, it is unlikely that they will consider this experience a failure as long as they meet their internal criteria around effort. Conversely, it is possible that for students who link failure with a lack of effort, courses, assignments, or assessments that fail to motivate them, or to provide opportunities for exertion, could lead to Category 3 failures. An experience that provides too little challenge may cause these students to believe that they are failing, regardless of process or outcomes. As an example, Alex said "coming out of a course with no understanding of the material, even, even after earning a passing grade" would be a major failure.

The results of this work indicate the need for new measures of failure that not only incorporate current definitions of failure based in learning science and education theory but also account for the unique ways in which students describe failure. One such measure could include scenario-based measures that manipulate contexts to better pinpoint which factors are salient in each student's definition and experience of failure.

Future Work

Future qualitative work is focused on further data analysis and collection efforts across different universities and course types to help broaden student perspectives, which is essential in the development of personalization. To date, we have focused on measuring student perceptions related to their failure responses, such as their engineering role identity [27] and perceived fear of failure [24], consistent with outcome-oriented framings. We have also collected student course observation data for four types of courses at the institutions of study, consisting of audio and video feeds of the students engaging in problem-solving, tracked biometrics using an Emotibit device [35], and follow-up critical incident interviews covering the students' experiences in the problem-solving activity, consistent with process-oriented framings. Our next steps for this work will be triangulating these streams to make data-informed claims about student failure experiences from an integrated framing and incorporating the student voice in how to design personalized learning environments that embrace failure as positive and essential in learning and development.

Conclusion

In this work, we have explored students' definitions of failure in order to understand how it juxtaposes with the definitions of failure used in the learning sciences and education literature. We found varying definitions of failure across the 11 student participants we interviewed. In contrast to previous work on failure, our work is novel in its focus on students' definitions. We also discovered important differences between participants' definitions of failure and those used in the literature, creating the possibility that carefully designed Productive Failure learning activities could support the positive outcomes of failure while avoiding the deleterious consequences reported in previous work. Finally, while we view the differences between students' definitions of failure and those drawn from the literature as an opportunity, they also represent a risk for miscommunication between researchers, students, and educators. Care should be taken to clearly define failure when discussing it in engineering education due to the contextually-dependent nature of failure. The field of engineering education should continue to hone and adapt these failure definitions to better understand failure from all perspectives, including those of students, instructors, and professional engineers, to continue improving failure-based education efforts.

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Appendix

Table A1: Failure Definitions Codebook Sample

Subcode	Definition	Example Quote	Quote source
Absolute Grades	Failure defined in terms of an absolute grade without context	My goal at the end of the day is to get around the A range in all of my classes	Felix
Comparative Grades	Failure defined in terms of a grade or score relative to other students or to a statistical measure	What are other people doing? What could I be doing? How are other people doing better than I am? Is kind of intrinsic to, kind of my definition of failure.	Harper
Outcome worse than expectations	Failure defined in terms of an outcome not meeting their expectations	Failure is going back to just not meeting an expectation or an objective or a goal	Liam
Emotional consequences	Failure defined in terms of the emotional consequences	I think that sort of a minor failure sort of thing would have been like, like something that might feel very bad one day, but I won't remember in like a week	Gabriel
Mastery	Failure defined in terms of not mastering or learning the material	Coming out of a course with no understanding of the material, even, even after earning a passing grade, if I, if I come out of a class and I have no idea what's going on to me, that's a failure.	Alex
Maladaptive response	Failure defined in terms of a maladaptive response	When I've really failed is when I had a set back and I wasn't able to pick myself up again. So let's say I got the... so I got below median on the chem test. Failure for me would be if I let that that set back affect my entire college grade	Alex
Effort	Failure defined as a lack of effort	Failure is like when I didn't put in as much effort as I should have, and therefore didn't get everything I wanted out of it,	Ghana
Long-term consequences	Failure defined in terms of an event having long-term negative consequences	It's something that's going to have long term consequences. Which can, you know, vary, like the poor test grade that's going to reflect on my GPA for the rest of that course	Gabriel
Non Academic	Non-academic failure defined	Not developing any social connections while you're at university. I think that's a pretty major failure	Alex