PILOT STUDY UNDERSTANDING STUDENTS' PERCEPTIONS OF FAILURE IN PRODUCT DESIGN

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ABSTRACT

Failure is part of the design process, and yet there is limited knowledge around how product design students perceive failure in their work. This pilot study aims to understand how a small sample size of undergraduate product design students conceptualize success and failure during specific stages of their design projects. This study uses a two-step data collection and analysis process. First, we collected responses from students on topics related to success and failure in a survey. Second, interviews were conducted with a subset of the survey respondents where these emergent topics were discussed and refined. In analyzing the responses, the research team used the Double Diamond Design process framework to organize what factors students deemed a success or failure within each stage. In summary, our preliminary findings indicate that determining success or failure is driven by the connection to the problem statement regardless of the stage; that student designers refer to failure as a spectrum but then in their examples showcase a binary view on the topic; and that examples of failure are often the opposite of success, reinforcing the notion of binary success vs. failure during student design projects.

Keywords: Design process, New product development, Failure, Design cognition, Design education

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1 INTRODUCTION & BACKGROUND

"The concept of failure, which plays a central role in successful design, is viewed as a unifying principle of the whole design process" (Petroski, 1989). Even though failure occurs in design, there is limited research exploring how individual designers orient towards, enact, and respond to failure during the design process. But what exactly is failure? Failure can range in definition from "omission" to "lack of success" to the concept of "falling short". There is continued debate on what constitutes failure in design. On one hand, some researchers discuss failure as an opportunity for learning, concluding that your perspective on failure may be seen as a success from another person's perspective (Gaver et al, 2009). Conversely, others view failure as a break-down in the product or system that should be mitigated and avoided through risk-management (Gidel et al, 2005). Instead of viewing failure in a binary fashion, either you failed or did not fail, we take the perspective that failure occurs along a spectrum and is situated in different contexts (Edmonson, 2011). Edmonson established a spectrum of reasons for failure ranging from blameworthy failure, like deviance, to praiseworthy failure, like exploratory and hypothesis testing. Students often learn that failure in design should be avoided, since failure translates to loss in time, money, and resources. This binary view can influence designers' approach to problem-solving, and potentially cause designers' to be risk averse. As truly innovative and creative ideas are often seen as riskier than less innovative or creative ideas (Zheng & Miller, 2017), we highlight this as a significant problem within design pedagogy.

In comparison, success in design has often been defined by the ability of the final solution to meet or exceed the problem constraints, project requirements, or customer needs (Ulrich & Eppinger, 2011). From the perspective of professional practice, success is almost entirely defined by design outcomes. Design also has a lot of uncertainty, and researchers have studied the cost of learning from failures in product design (Shafqat et al, 2019). In the context of design education, success might not always be a perfectly functioning or high-quality final design. Instead, success may look like the synthesis of new knowledge and skills that advance the student's educational goals. To expand upon this, we adopt Dweck's social cognitive theory of achievement motivation. In their seminal work, Dweck et al. (1988) proposed two distinct goals within educational environments: performance goals (gain positive and avoid negative judgements of ability) or learning goals (increase competence). These distinct goals produce unique patterns of affect, cognition, and behavior, within students and are guided by implicit individual beliefs. In the current work, we investigate students' perceptions of both failure and success, as we hypothesize, they may be inextricably intertwined. Specifically, students' perceptions of success or failure may depend on their ability to recognize failure as an opportunity for growth, thus reframing failure as success from the perspective of a learning goal. The guiding research question for this study is: How do product design students perceive failure and success in relation to their design projects both overall and at different design process stages?

Design students are often taught about different design process models; they range in number of stages and steps, as well in how they are visualized and the methods and activities that are included. One popular model is the Double Diamond design process model (UK Design Council, 2013). This model has been called many things, such as the Design Innovation process (Wood et al, 2021). The process model has four stages: Discover, where you diverge in thought to understand a problem; Define, where you converge and synthesize to a refined problem statement; Develop, where you diverge and develop concepts to solve your problem; Deliver, where you converge to a prototype or model to solve your problem. In the current work we explore student designers' conceptualization of failure within the context of the Double Diamond design process. We are interested in understanding how students define failure in specific process stages and how this relates to perceived performance on the project overall. We hypothesize that students would define failure differently in each stage of the design process. This work, while an early exploratory study, will add to the limited literature on failure within design. The goal of this work and future research on this topic would be to have a direct impact on design education; we hypothesize that outcomes from this and future work could inform re-design of course assets like rubrics and evaluation forms. We anticipate findings informing how instructors frame failure within the design process, encouraging resilience and grit amongst design students, and being more intentional about having these conversations on "failure" with students.

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2 RESEARCH STUDY APPROACH

This is an exploratory, qualitative research study. This research was conducted in compliance with the local Institutional Review Board guidelines, under STUDY00012860 at the University of Minnesota. The guiding research question for this study is: *How do product design students perceive failure and success in relation to their design projects both overall and at different design process stages?*

2.1 Study population

Senior product design students from their capstone project course during 2022-23 were recruited to participate in this study. In compliance with the IRB and ethical standards, all participants were given pseudonyms to ensure their data remained anonymous and confidential. Pseudonyms were given to each respondent at the end of the survey. The only researcher that knew the participants identity was the lead student researcher. In all discussions with the other research team members, pseudonyms were used for the participants. These product design students were in the fourth year of the program, meaning that they had participated in at least four previous design studio courses and engaged in coursework that covered technical skills like concept sketching, computer aided design, engineering, and prototyping. There were 25 students in the course, and all of them were invited to respond to the initial survey; in total, there were seven survey respondents and three who participated in interviews. We did not collect any demographic information on the students. The three students that participated in the interviews had to opt-in to being contacted at the end of the survey. They would then need to list their email address, and the lead student researcher would contact them to set up a survey. The lead student researcher would continue to collect data during the interviews using that student's given pseudonym. The capstone course is a two-semester studio based course. The projects of the students are self-directed with feedback from the instructor and industry mentors, and they range from developing new medical devices to shoes. The instructor introduced multiple design process frameworks in the beginning of class and used the structure of the double diamond process to guide the four major milestone points for the course.

2.2 Data collection and analysis

Data was collected via survey to assess students' perceptions of failure; items from the survey are shown in Table 1. Follow-up interviews were then conducted with a subset of the students to deepen our understanding of the responses from the survey. As failure is generally considered to be a negative outcome due to widely held societal norms, the likelihood that students' responses would be affected by social desirability bias, or the tendency to answer questions in a manner that would be viewed favorably by others, was high. As such, the research team aimed to minimize social desirability bias by carefully constructing questions to ask about student's perceptions of failure more broadly. Additionally, as is best practice in psychometric research (Messick, 1998), we employed a form of reversed items, asking students to describe their perceptions of both failure and success, in both the surveys and the interviews.

Engineering education researchers often use theories of reflective practice to motivate the use of written or verbal reflection during educational activities such as problem solving (Douglas et a., 2012); engineering design (Adams, Turns & Atman, 2003; Dym et al, 2005) since reflection-in-action and reflection-on-action are both critical to learning. The current work employed open-ended survey items to encourage reflective practice amongst practitioners; specifically, students were asked to reflect upon their conceptions of failure and success within a recent design project. For example, students were asked to describe a time in their product design project where they were successful (see Table 1). Students were also asked to reflect upon specific stages of the design process, using the Double Diamond Design process as a framework. For example, students were asked "what does failure look like in the discover phase". Finally, the survey concluded with two open ended questions that asked students to reflect upon the relationship between failure and success. Prior to distribution, the survey underwent three iterations before being administered to the product design students. First, the researchers internally reviewed the questions. Then, the survey was pilot tested with a third-year product design student and their feedback informed the final survey, which was reviewed again by the research team. The final survey questions are shown in Table 1.

Data from the surveys was analyzed before interviews were conducted. The researchers engaged in an inductive content analysis (Bengtsson, 2015), looking at topics that emerged related to success and

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failure in the written responses without interpretation of the meaning. Initially, the lead student researcher read the responses to the survey questions asking, "what has been said?" and identifying and coding the written text with factors that relate to failure in design projects overall. After reviewing all seven students' responses, we then compared the topics across the students. Since some questions in the survey asked about success, the student researcher would also compare factors for success with the factors for failure to see if there was any connection between them. Since failure can be discussed both as binary (i.e., success vs. failure) and as a spectrum (i.e., praiseworthy failure to blameworthy failure), we aimed to learn more about how students conceptualize failure. While not a primary goal of this project, we aimed to understand if student designers think about success and failure on a spectrum or as binary factors. Throughout this emergent and iterative coding process, the lead student researcher met with the research team to review themes on a weekly basis, review coded text, and iterate on topics identified. With such a small data set, we did not develop a full codebook for the seven survey responses and three interviews, but rather identified all the factors for failure to gain a better baseline understanding of how product design students perceive failure in their design projects. Next, the identified factors and instances of failure were then segmented by the stage of the design process. This helped the researchers understand what constituted failure during designated steps of the design process, and if this was different than failure of the design project overall. As a reminder, this is the Double Diamond design process framework, and it is the process used by this product design capstone course.

After analyzing the survey's responses, interviews were conducted with a subset of the students who filled out the survey. Students had to opt-in during the survey to be contacted for an interview. There were six students from the seven survey responses who were interested in a follow-up interview, and ultimately three interviews were able to be scheduled. Interviews followed a semi-structured format with a mix of predetermined questions to dig deeper into the survey questions and prior students' responses, as well as allowing space in the interview to explore concepts and ideas as they arose. Each interview was slightly different as the questions were adjusted based on emergent findings from prior interviews. The goal of the interviews was to develop a deeper understanding of the causes of failing in each stage and in the whole design process. All interviews were conducted over Zoom and data was collected by note taking from the lead researcher. Interviews lasted for approximately one hour each. The notes were then analyzed like the survey responses, by looking at themes in failure overall and then identifying specific instances of failure for each stage of the design process.

Table 1. Final survey questions, categorized by question function for this paper only.

Question Function	**Survey Questions**
Broad exploratory questions on success and failure in entire design process. (Goal: 100 words or 5 sentences)	Describe a time in your product design (PD) project where you were successful. Explain the context of the event, what led to this success, what the results of the success were, and additional details about this experience.
	Describe a time in your product design project where you failed or felt like a failure. Explain the context of the event, what led to this success, what the results of the success failure, and additional details about this experience.
Broad questions with specific instances on success and failure in entire design process	List 5-10 moments, events, or experiences within a PD project that are considered successes.
	List 5-10 moments, events, or experiences within a PD project that are considered failures.
Specific questions about success and failure at each design process stage	In PD process, what does success and failure look like in the discover phase?
	In PD process, what does success and failure look like in the define phase?
	In PD process, what does success and failure look like in the develop phase?
	In the PD process, what does success and failure look like in the deliver phase?
Understanding relationship between success and failure	Is it possible to have both successes and failures on the same project?
	If in one project you have had both failures and successes, what determines whether the project is a failure or success? Do you have to choose between the two? (3-4 sentences)

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2.3 Research limitations

There are several limiting factors in this research. This study uses a very small population of senior product design students at one university in North America. The research was conducted during one semester (16 weeks), which limited the time scale for both the design projects and research conducted on the class. In the future, a longer project timeline with more students would be beneficial. The survey asked questions about both success and failure; having both responses required may cause survey fatigue, and it also may influence how students respond to the questions. Additionally, because this research is qualitative and exploratory, there is potential that some perceptions were excluded, missed, or inaccurately represented. The researchers report the findings as truthfully as they can but note that biases often occur even with the best intentions. In the responses from students, there were some students that may have been more clear or expressive than other students, which could have created a bias in the data analysis and reported findings.

3 EMERGENT FINDINGS

These emergent findings come from a small sample of data. As such, we report findings from this dataset, but recognize that these are not necessarily validated or representative findings of all design students. Rather, these findings are seen as emergent themes that require further exploration. This section is organized as follows: first we discuss a subtle modification to the Double Diamond process as described by the product design students and then we discuss findings related to success and failure at each of the four stages. Following, we include a discussion of interesting emergent themes from the pilot study that will inform future work.

3.1 Modified double diamond process

While the class followed the Double Diamond design process, in the students' responses, they often grouped these stages slightly differently. Students referenced many of the same factors for failure in the research and synthesis stages. Therefore, for the purposes of this paper, the two stages (discover and define) were combined into one "Research and Synthesis" stage. Students discussed the ideation phase on its own (develop), often referencing sketching and brainstorming as main activities occurring in this phase. In the final deliver stage, students discussed two distinctly different topics - the many iterations of prototyping and then the final presentation to the client, end user, or other key stakeholders. For the purposes of this paper, we divided the deliver phase into "Prototyping" and "Presentation" stages. This is a slightly modified version of the Double Diamond process; instead of discover, define, develop, deliver we report findings in the stages of research and synthesis, ideation, prototyping, and presentation as this was how the stages were portrayed by the students.

3.1.1 Stage 1 - research and synthesis

Within the Research and Synthesis phase, students identified that developing a connection between the designer and end user as one of the most important factors to success in this stage. This aligns well with prior work, which highlights that creating connections with the people you are designing for allows you to better understand their needs, pain points, and experiences (Li & Hölttä-Otto, 2022). Students also identified that the quality of the information gathered during this phase was critical to success in this phase. Students expressed that these activities of research and synthesis worked in tandem to inform the formation of the problem statement that would guide the rest of the design activities. One student discussed the importance of doing secondary research (i.e., literature review) prior to any primary research (i.e., interviews) to better understand context and develop questions to ask during interviews. One student explained, "The more people you can talk to can be super beneficial and can contribute to… defining a problem to solve. If you don't do this, you can potentially not solve a real problem or miss out on something entirely." For example, the students who engaged in diligent secondary research and planning, felt they were able to have more meaningful conversations with users and formulate better problem statements. However, it was noted by another student that "you can't stay in research mode forever; ultimately you need to make a decision to move forward." Students noted that figuring out that balance can be difficult in "real world" projects, but that within academic, time-bounded studio classes there was a limit to the time and number of interviews that could reasonably be completed.

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Emergent findings indicated that oftentimes how well the designer understands the problem, and subtle nuances to the users and the problem, will then determine the quality of their reframed problem statement. Many students identified the ability to define the problem statement well and connect the problem statement to latent needs as key to determining success or failure during the research and synthesis phase. Students perceived problem statements that were ill-defined or not reasonably connected to user data as a sign of failure in the research and synthesis phase. One student shared, "a high-quality problem statement meets the following criteria: it is specific to the challenge, applicable to an appropriate range of users, addresses unresolved problems, and leaves room for exploration." The student then explained that as part of defining the problem statement success in this stage includes, "[determining] problem scope… problem solvability and necessity." A summary of identified emergent factors determining success and failure in the research and synthesis stage can be viewed in Table 2.

Table 2. Emergent factors for failure or success in the research and synthesis stage.

Emergent Factors	Examples of Success	Examples of Failure
Having a high-quality connection to the stakeholder/user	-Variety of individuals who represent the user demographics -Interviewees are involved -Interviews add valuable information, moves project forward	-Interviews do not narrow the problem statement or provide additional information for the designer -Not enough interviews to get a clear picture of the problem or experiences of stakeholders
Gathering quality information	-Research does not skew towards designer's bias -Information gathered further defines the problem statement	-Designer uses outdated research -Research does not add information to designer's understanding of the problem
Developing a high-quality problem statement	-Specific to the challenge -Applicable to range of users -Addresses an unsolved problem -Leaves room for exploration	-Problem statement is too broad -It seeks to answer a problem that already has a solution (lacks novelty) -Too specific, lacks space for creativity

3.1.2 Stage 2 - ideation

In the ideation stage, students identified idea quantity and idea creativity as leading factors impacting the overall idea quality. One student stated that you must "have a good number of ideation sketches because the number of concepts [you develop] corresponds directly to creativity of your [designs]." Many students cited research that they learned about through the product design program, such as the higher quantity of ideas you produce is related to the overall idea creativity (Kudrowitz & Wallace, 2013). While novelty is a criterion of a high-quality idea, novelty alone does not indicate success (Fiorineschi & Rotini, 2021). One student said, "It is great to have many novel ideas but if they are so outside of the box that they are unrealistic it ultimately will not be useful for solving the user's problem." From the student responses, it appears that success in this stage requires finding a quality idea, whereas failure at this stage includes not identifying a quality idea. Another student defined quality ideas as "unique/novel, pragmatic/realistic, and directly addressing or solving the problem." Concepts that are not considered novel, feasible, or that solve the identified problem, are more often linked with failure at this stage. Another student stated, "In the ideation phase, I think the worst thing you could do is to limit the amount of sketches you create. The more you ideate on the more you get feedback on those, usually the better your product or service will be. If you just go with the first thing you think of, once again you'd miss the real problem that you are solving." Another student stated that "even if you come up with hundreds of concepts, it doesn't matter if you don't keep your problem and research in the back of your mind." This indicates that success in this stage may be linked to having a high-quality concept that meets the needs of the previously identified problem statement from the research and synthesis stage.

A summary of identified emergent factors determining success and failure in the ideation stage can be viewed in Table 3. Emergent examples of success in this stage include having many sketches and ideas that are likely to answer the project goal. Student examples of failure are minimizing the number of sketches, being disconnected from the problem statement, or having to redesign or revisit this stage after moving forward in the process.

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Table 3. Emergent factors determining failure or success in the ideation stage.

Emergent Factors	Examples of Success	Examples of Failure
Idea Quantity & Creativity	-Trying many ideas, designer explores "non-normal" ideas to increase novelty -Having multiple ideas to solve the same problem	-Minimal sketches -Ideating too far where designer is then distracted from the problem statement -Generating ideas that already exist
Idea Quality	-Ideas are pragmatic and feasible -Ideas are novel and creative -Ideas address and potentially solve the problem statement	-Redesigning/Returning to this stage after moving to following stages -Ideas are vague and do not address the problem statement

3.1.3 Stage 3 - prototyping

The prototyping phase is more iterative, and therefore, led to more determining factors of success/failure when compared to the other stages. This stage includes bringing the idea into reality and moving towards creating the final prototype/product. During the interviews, students mentioned that there is "a lot more trial and error during prototyping compared to the other stages, which naturally leads to some failure." However, students reported conflicting statements about the amount of failure possible during prototyping; one student said, "prototyping is where failure happens most often" whereas another student said, "the only way I can think of failing at prototyping is to not do any [prototyping]." In these two statements, one student believes failure happens "most often" indicating that failure is required at this stage, whereas the student only views failure as the absence of creating a prototype at all.

In this stage, there are often multiple prototypes created. One student discussed how "each iteration [of the prototype] doesn't have to meet [all] the standards of the final prototype; however, it needs to highlight what does and doesn't work for it to be successful." For example, if the goal is to make a works-like model, then the prototype needs to be functional to be a success, but it does not have to meet the aesthetic standards of the final product. Multiple students indicated that a lack of learning from each prototype was a failure. Conversely, learning from the prototype (even if it did not work) and then improving your design in the next iteration is considered a success. Here is an example as explained by one student, "in the first prototype I used a paint which is much too thin and left the [aesthetic] look [of the model] very blotchy, I learned from this and in the following iteration I used a new paint which is thicker and looks [a lot] better." This student learned about a specific aspect of the prototype (paint, aesthetic look) and then used that learning to improve the next model; therefore, this was seen as a success even though not everything was done right in the first model. Another student expressed that failure in this stage is, "spending a lot of time on a product that is misguided or not connected to the goal. It also could be a failure if the prototype doesn't move [the project] forward in any way." Another student said that failure is beneficial in this stage, "because then you know what could be made better in the future and then create that better prototype to retest again." In these statements, we see that it is hard to determine success/failure when looking at the prototype alone. Rather, the full trajectory of this stage is needed to see how the student takes (or does not take) the learnings forward into the next model. Overall, students tended to agree on what constitutes success - acting on prior learnings. As one student said, "success is any failure from early [prototypes] which you then revise in later [prototypes]." A summary of identified emergent factors determining success and failure in the prototyping stage can be viewed in Table 4.

Table 4. Emergent factors determining failure or success in the prototyping stage.

Emergent Factors	Examples of Success	Examples of Failure
There is "learning" from each iteration of the prototype which the final integrates together	-Iterations improve from feedback, such as looks-like and works-like models -Iterations that must be redone turn out better in the opinion of the designer	-Concepts do not come to life and designer must return to ideation phase -Damaging the prototype and having to restart an iteration -Having few iterations
Quality of the final prototype	-Finish/painting is done well -Product is functional -Solves or answers the problem statement	-Finishes or painting done wrong -Final product is not functional or not presentable -Doesn't solve problem statement

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3.1.4 Stage 4 - presentation

The last stage of the design process as described by the students is the presentation stage. This is the designer's opportunity to share their product with stakeholders and end users. One student mentioned that this stage is not the longest or most laborious stage, but it is very important because it determines whether their products will be used. The importance of this stage is emphasized by one student, who also considers this stage to also determine overall success saying, "The final deliverable critique is what determines if a project is a failure or success… you aren't designing for you, you are designing for the user. If the solution satisfies the user's needs, then the project is a success. If not, it is a failure." Stage-specific success criteria includes that the product is aesthetically pleasing, that the audience is convinced that the product addresses the problem statement, the product solves all or part of the problem, and that the presentation is appropriate to stakeholders. A summary of identified emergent factors determining success and failure in the presentation stage can be viewed in Table 5.

Table 5. Emergent factors determining failure or success in the presentation stage.

Emergent Factors	Examples of Success	Examples of Failure
Final product aesthetics	-Overall, aesthetically pleasing (ex: clean, visually appealing)	-Product is not aesthetically pleasing (ex: messy, unfinished)
Stakeholder or final user's opinion	-Stakeholder easily understands the final product's function -Final product solves or partially solves the problem statement	-The final product is not usable for the stakeholder -The problem statement is not solved at all by the product

4 DISCUSSION OF FINDINGS

4.1 Contextual factors, project goals & problem statements

This research project sought to understand how product design students perceive success and failure in relation to their design projects, both overall and at different design process stages. One contextual factor that appears to play a large role in the findings is that these design projects occur within a university, which create constraints like shorter time-bound projects and grades associated with the projects, which become hard to delineate from many of the responses and stories from the product design students. Success to some students is tied too closely to "passing the class", and conversely failure is often attributed to "failing" the course based on a letter grade. While the grade received can be traced back to rubrics with specific criteria outlined, it is still difficult to identify what else defines success/failure. It also appears that students are taught what success looks like at each stage through the detailed expectations at each milestone. However, students are not taught what failure looks like, and it seems like many of the respondents choose to list the "opposite" from the criteria on the rubric or else the absence of doing anything at all during that stage of the project. For example, in the ideation stage having a final high-quality concept (novel, feasible, useful) is deemed a success by many of the students. Conversely, not developing a concept at all or not developing a concept that meets those criteria or connects back to the identified problem statement would be a failure.

It also appears that the goals of the project can drive what determines success or failure. One student articulated this well stating, "I think projects can be both a success and failure in the end, depending on your goals. If the only goal is to make the grade, focusing on the minuscule details [in the rubrics] will lead you to success. But if the goal is to decide whether to put a product on the market, the benchmark for success becomes something else entirely." In this instance, a project that receives an "A" in a class might be determined a success, but if this same project was trying to launch that product to market and was not able to do that then it would likely be a "failure". The same project can have two different outcomes (success vs. failure) depending on the onset goals for the designer. Being that the designers in this study are also senior product design students, their goals for a project are partially related to course context (i.e. grades, rubric). The goals are also tied to students' individual desires, such as to improve certain skills or deliver a solution that solves a real problem and identified need. These individual goals are something that are not explicitly asked for in this course but could be helpful in the future for articulating success or failure at each stage and overall. It seems as if these goals need to be explicit from the start of a project or else it becomes difficult to measure the level of success or failure.

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One recurring topic across all stages of the design process was that success and failure at each stage is evaluated through the lens of the problem statement. In this product design capstone course, the problem statement is created at the end of the define stage, after all research and synthesis is complete. This means that there is flexibility in the statements, but they must be informed by real research. Throughout the analysis, there continued to be a strong connection between the level of success/failure at each stage and the connection to the problem statement. It appears that the problem statement guides students towards the project goals, and that the goals for a project are a way to self-assess your level of success or failure. and it became clear throughout the interviews that orientation towards the problem statement was critical to both overall success in the design project and for stage-specific success as well.

4.2 Success and failure - binary or spectrum?

An interesting observation from this research was that students often had a much easier time discussing instances of success than they did discussing failure. Additionally, during interviews most students explained that the overall success or failure of a project falls on the spectrum with failure on one end and success on the other. However, students had difficulty identifying what incomplete success or failure looked like. When asked for an example of what a project that is neither successful or a failure looks like, students in the interviews were unable to think of one example even though all seven students responded "yes" on the survey when asked if there could be both failure and success in the same project. Since there is a slight disconnect between what students say and what they do, we believe that this "middle of the spectrum" from success to failure is a topic worth further researching. We hypothesize that the middle of the spectrum for overall projects is a mixture of success and failure at each stage of the process. Therefore, identifying what success or failure looks like at each stage might be important to better understanding what an overall partial success or partial failure might look like.

In both the surveys and interviews, students described success and failure as a binary in the examples that they gave, despite indicating that they view success/failure on a spectrum. Additionally, across most of the stages of the design process, students often listed the "opposite" of success as the failure. For example, in the research and synthesis stage, students indicated that developing a high-quality problem statement (i.e., being specific yet having room for exploration in the statement, addresses real needs from research, applicable to a range of users) was indicative of success at this stage. Conversely, a problem statement that was too broad, lacks room for exploration, or answers an already answered problem was considered lower quality and a failure at this stage of the process. These "opposite" answers for determining factors of success and failure may be in part due to the way the questions were phrased in the survey (asking for both success and failure), and also due to the fact that these projects were within an academic course where success criteria are defined and failure criteria are not defined.

Regardless, this indicates the need for more research on the concept of "failure on a spectrum" for designers. There are numerous questions that still need answered, such as: Are success and failure always opposite to one another? Are there factors that relate more to one over the other? When designers meet some, but not all, of the criteria in a stage is their partial failure or partial success or both? How does failure in one stage affect the success or failure of another? How do the onset goals for the project impact success or failure? How does the failure spectrum change when students work in teams? Finally given the focus on what stage specific success and failure from this pilot study, it is recommended that there is further investigation into what determines whether a project is an overall success or failure.

5 SUMMARY

This was an exploratory pilot study aimed at gaining an initial understanding of product design students' perception of failure and success during design projects. The preliminary findings indicate that students view failure and success differently in each stage of the design process, with specific factors playing a role at each stage. In the research and synthesis phase, factors like connection to the stakeholder/user, gathering quality information and developing a high-quality problem statement were important. In the ideation phase, factors like idea quantity and level of creativity as well as idea quality (in relation to the problem statement) were discussed. In the prototyping phase, factors like learning from each prototype iteration and the overall quality of the final prototype (in relation to the problem statement) were

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important. Finally, in the presentation phase factors like the final product aesthetics and stakeholder or end user's opinion were the most important criteria for determining success or failure.

In summary, our preliminary findings indicate that determining success or failure is driven by the connection to the problem statement regardless of the stage and that project goals, both academic and self-initiated, can connect to students' identification of success/failure. It also appears that students think about failure and success as opposite sides of the same spectrum, but that they have difficulty defining the middle portion of this spectrum and, therefore, end up sharing examples of success/failure that appear more binary. These early insights can provide direction for future studies on failure in design; and as can be expected from early exploratory research, we are left with more questions than answers. The hope is that this research and future research on this topic can positively impact design education, through prompting instructors to assess how they discuss and evaluate failure in their project courses.

REFERENCES

Adams, R.S., Turns, J. and Atman, C.J., 2003. Educating effective engineering designers: The role of reflective practice. Design studies, 24(3), pp.275-294. https://doi.org/10.1016/S0142-694X(02)00056-X

Bengtsson, M., 2016. How to plan and perform a qualitative study using content analysis. NursingPlus, pp.8-14. https://doi.org/10.1016/j.npls.2016.01.001

Douglas, E.P., Koro-Ljungberg, M., McNeill, N.J., Malcolm, Z.T. and Therriault, D.J., 2012. Moving beyond formulas and fixations: solving open-ended engineering problems. European Journal of Engineering Education, 37(6), pp.627-651. https://doi.org/10.1080/03043797.2012.738358

Dweck, C.S. and Leggett, E.L., 1988. A social-cognitive approach to motivation and personality. Psychological review, 95(2), p.256. https://doi.org/10.1037/0033-295X.95.2.256

Dym, C.L., Agogino, A.M., Eris, O., Frey, D.D. and Leifer, L.J., 2005. Engineering design thinking, teaching, and learning. Journal of engineering education, 94(1), pp.103-120. https://doi.org/10.1002/j.2168-9830.2005.tb00832.x

Edmondson, A.C., 2011. Strategies for learning from failure. Harvard business review, 89(4), pp.48-55.

Fiorineschi, L. and Rotini, F., 2021. Novelty metrics in engineering design. Journal of Engineering Design, 32(11), pp.590-620. https://doi.org/10.1080/09544828.2021.1928024

Gaver, W., Bowers, J., Kerridge, T., Boucher, A. and Jarvis, N., 2009, April. Anatomy of a failure: how we knew when our design went wrong, and what we learned from it. SIGCHI (pp. 2213-2222). https://doi.org/10.1145/1518701.1519040

Gidel, T., Gautier, R. and Duchamp, R., 2005. Decision-making framework methodology: an original approach to project risk management in new product design. Journal of Engineering Design, 16(1), pp.1-23. https://doi.org/10.1080/09544820512331325238

Kudrowitz, B.M. and Wallace, D., 2013. Assessing the quality of ideas from prolific, early-stage product ideation. Journal of Engineering Design, 24(2), pp.120-139. https://doi.org/10.1080/09544828.2012.676633

Li, J. and Hölttä-Otto, K., 2022, August. Does Empathising With Users Contribute to Better Need Finding?. In IDETC-CIE (Vol. 86267, p. V006T06A023). ASME. https://doi.org/10.1115/DETC2022-89413

Messick, S., 1998. Test validity: A matter of consequence. Social Indicators Research, 45(1), pp.35-44.

Petroski, H., 1989. Failure as a unifying theme in design. Design Studies, 10(4), pp.214-218. https://doi.org/10.1016/0142-694X(89)90004-5

Shafqat, A., Oehmen, J., Welo, T. and Willumsen, P., 2019. The cost of learning from failures and mistakes in product design: Reviewing the literature. ICED (Vol. 1, No. 1, pp. 1653-1662). Cambridge University Press. https://doi.org/10.1017/dsi.2019.171

UK Design Council, 2013. Design for public good. Annual Review of Policy Design, 1(1), pp.1-50.

Ulrich, K. and Eppinger, S., 2011. EBOOK: Product Design and Development. McGraw Hill. ISBN10: 1260043657

Wood, K., Lauff, C., Yu Hui, W., Teo, K., Png, S., Swee, A., & Vargas, B. (2021). Design Innovation Methodology Handbook–Embedding Design in Organizations. (SUTD-MIT IDC). ISBN: 978-981-18-1207-1

Zheng, X. and Miller, S.R., 2017, August. Risky business: the driving factors of creative risk taking attitudes in engineering design industry. In IDETC-CIE (Vol. 58219, p. V007T06A028). ASME. https://doi.org/10.1115/DETC2017-67799

https://doi.org/10.1017/pds.2023.290 Published online by Cambridge University Press