Influences of feedback interventions on student concept generation and development practices

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Abstract: *Design teaching in many disciplines relies on feedback as a primary way for students and instructors to communicate. Our work focused on identifying feedback types in three different design disciplines (dance choreography, industrial design, and mechanical engineering) and analyzing how those feedback types encouraged students to take convergent or divergent paths with their design ideas. We then compared feedback types and encouragement of convergence or divergence across the three disciplines. Our findings showed many common types of feedback used across the three disciplines, regardless of variance in context and expectations. However, the findings also revealed a high frequency of feedback suggesting convergence or not pushing in either direction. While design processes aim to identify the most promising solution through a series of convergence steps, divergence is equally critical throughout the entire process, and this work suggests a consideration of when and how to integrate feedback supporting divergence throughout design processes.*

Keywords: ideation, divergence, convergence, design processes

1. Introduction

Engineering and design education emphasize project-based courses (Bright, 1994; Dutson, Todd, Magleby, & Sorensen, 1997; Dym & Little, 2004), such as cornerstone and capstone engineering design courses and design studio courses, to support student learning about design processes and strategies. These design courses have been developed to better prepare graduates for discovery and innovation and to create a smooth transition from academic education to the workforce (King, Young, & Behnke, 2000; Todd, Magleby, Sorenson, Swan, & Anthony, 1995). Success in teaching these courses in any discipline relies, in part, on the ability of the instructor to provide guidance and feedback on students' design paths and processes, allowing them to explore on their own, but facilitating a structure where the students can learn strategies to fully explore the problems, analyze and refine problem statements, engage in divergent processes by generating a wide range of solutions and converge and verify their most promising outcomes

While project-based learning has been shown to be an effective pedagogy to support student engagement (Eastman, Newstetter, & McCracken, 1999; Smith, Sheppard, Johnson, & Johnson, 2005), little research has investigated the types of feedback instructors give to their students at various stages in their design projects, and specifically how this feedback relates to concept generation and development and how it guides students in convergent and divergent thinking. Successful development of an idea involves both types of thinking, meaning there are times when designers must see new possibilities, generate multiple ideas for consideration, and take risks, as well as times when designers must analyze and evaluate to narrow down problem criteria and ideas to one (or a few). (Brophy, 2001; Cropley, 2006; Cross, 2001; Dym & Little, 2004; Guilford, 1984; Liu, Bligh, & Chakrabarti, 2003). While overall design processes, and the paths toward a final design artifact, are convergent in nature, process models represent both types of design thinking throughout (e.g., Banathy, 1996; Cross, 2000). The choices created (divergent thinking) may get less broad, and the choices evaluated and executed (convergent thinking) may get more frequent as designs move toward final products.

Guided by Goel & Pirolli's (1992) characterization of design, many disciplines engage in design thinking, even though they may each use unique language to describe it. For example, a musical score is composed, a science experiment is developed, or a dance work is choreographed. Cross (1995) called design a discipline within itself, discussing the "commonalities of instances of design in different disciplines." Design literature incorporates a broad range of disciplines in discussions of designers; Nelson and Stolterman (2003) include engineering, industrial design, architecture, information design, software design, urban design, organizational design, educational design, and instructional design, and Zimring and Craig (2001) list engineering, architecture, computer science, industrial design, planning, and the performing arts. Studies on design that include multiple disciplinary design perspectives can provide rich results that allow for design disciplines to learn from each other (e.g., Cross & Roozenburg, 2008; Daly, 2008; Daly, Adams, & Bodner, 2012; Goldschmidt & Rogers, 2013; Lloyd and Scott, 1994; Purcell and Gero, 1996; Yilmaz, Daly, Seifert, & Gonzalez, 2010, 2013). Thus, our focus on feedback related to idea development, convergence, and divergence included multiple disciplinary perspectives, with the goal to transfer approaches and strategies across disciplines.

In our work, we explored instructor feedback in dance choreography, industrial design, and mechanical engineering. While the content of the design projects were unique to the discipline, students were engaging in design thinking in various ways, and responsible for generating and evaluating ideas, and developing those ideas into a final design outcome. Our goal was to understand how instructor feedback suggested particular thinking pathways (convergent or divergent) as ideas were created and developed, or did not direct students to either way of thought. By exploring feedback across disciplinary contexts, we aimed to understand how feedback types related to concept generation and development and how the feedback types were connected to encouraging convergence or divergence, and also to provide a means to share strategies across disciplinary boundaries.

2. Background

2.1 Concept Generation, Development, and Selection through Divergence and Convergence

Design thinking involves complex cognitive processes (Dym, Agogino, Eris, Frey, & Leifer, 2005) requiring designers to ask diverse questions, explore the problem and solution space in depth, generate a variety of options for pursuit, and thoroughly develop and evaluate promising pathways (Dorst & Cross, 2001; Maher, Poon, & Boulanger, 1996). Sheppard (2003) characterized engineering design as a process of scoping, generating, evaluating, and realizing ideas. Design is the route for developing innovations (Ottosson, 2001; Soosay & Hyland, 2004), and this path toward innovation begins with concept generation, where multiple and diverse concepts are created (Akin & Lin, 1995; Atman, Chimka, Bursic, & Nachtman, 1999; Daly, Yilmaz, Christian, Seifert, & Gonzalez, 2012; Liu et al., 2003). Designers then move through cycles of idea development, narrowing, and more generation to eventually determine a final design. These iterations require divergent thinking for creating choices to consider, and convergent thinking for narrowing and selecting from those choices.

In concept generation, a variety of ideas is considered a key component of success (Jansson & Smith, 1991; Shah, Smith, & Vargas-Hernandez, 2000; Nelson, Wilson, Rosen, & Yen, 2009; Srinivasan & Chakrabarti, 2010) where designers explore many different areas of the “design solution space” (following the notion of a “problem space” defined by Newell and Simon (1972)). Novelty is also considered a success criterion (Dean at al., 2006; Linsey, 2007; Shah et al., 2000; Peeters et al., 2010), where in this space of all potential solutions for a problem, designers create concepts that are not considered obvious, e.g., ones that come to mind more readily than others. While all designers have first ideas, fixation on a first obvious idea prematurely closes the design space and does not leave room for novel ideas (Cross, 2001; Jansson & Smith, 1991; Linsey et al., 2010; Purcell & Gero, 1996). Pushing past the obvious ideas requires divergent thinking, which includes shifting perspectives, seeing new possibilities, being unconventional, combining the disparate, taking risks, and producing multiple answers (Basadur, Graen, & Scandura, 1986; Basadur & Hausdorf, 2010; Cropley, 2006; Runco, 1991; 1993; Silvia et al., 2008). While design processes often have a phase labeled “concept generation,” concept generation happens throughout a design process, when one encounters a decision point and creates multiple ideas for options for the decision.

While divergent thinking is crucial to successful concept generation, convergent thinking is also vital as it determines the direction of the design embodiment stage (King & Sivaloganathan, 1999; Guilford, 1967). Convergent thinking refers to human cognitive activity that seeks a single or best solution through identifying familiar solutions, reapplying set techniques, and accumulating existing information (Cropley, 2006; Guilford, 1967; Runco, 2007; Weisberg, 1999). Convergent thinking is necessary to evaluate, synthesize, and select the most promising ideas, and ultimately the concept that will become the final design. Convergent thinking is also intimately linked to knowledge. On the one hand, it involves manipulation of existing knowledge by means of standard procedures, and on the other hand, its main result is the production of increased knowledge (Cropley, 2006). There are numerous approaches for concept selection in engineering, including intuition, feasibility judgment, multi-voting, numeric and non-numeric selection charts, pairwise comparisons, decision matrices, and prototype testing (Aurand, Roberts, & Shunk, 1998; Mullur, Mattson, & Messac, 2003; Otto, 1995; Pahl & Beitz, 1996; Pugh, 1996; Thurston & Carnahan, 1992; Ullman, 1992; Wang, 1997).

2.2 Design Instruction Feedback on Concept Generation, Development, and Selection

Novice designers must learn when and how to shift through the necessary cycles of divergent and convergent thinking in design. Through the structure of courses, assessment guidelines, and feedback provided, design instructors play a significant role in the choices made by students with regards to their design pathways (Dannels & Martin, 2008; Tolbert & Daly, 2013) and their eventual professional practices. Thus, it is important to understand how instructors guide students in the creation, development, iteration, and selection of ideas throughout a design experience.

Providing feedback is a foundational communication event in project-based design courses and is central to students' development of design expertise. In the fields of physiology, engineering, and mathematics (Littlejohn, 1992), feedback has been defined as an element in communication systems that provides information about progress and adjustments needed in subsequent approach and behavior (King et al., 2000). Feedback interventions are defined as actions taken by an external agent to provide information regarding some aspect of one's task performance (Kluger & DeNisi, 1996), in our case the actions taken by a design instructor to guide students design decisions and development of design knowledge. The effect of feedback interventions on performance has been examined by communication theorists (Annett, 1969; Balzer, Doherty, & O'Connor, 1989; Book, 1985; Jurma & Froelich, 1984; King & Behnke, 1999; King et al., 2000; Kluger & DeNisi, 1996). For example, Kluger & DeNisi (1996) found that message cues that draw attention to meta-task features (such as threats to face) weaken performance, while cues drawing attention to task motivation or learning processes enhance performance. King (2000) challenged the assumption that more feedback is always best, and argued that variables such as the nature of information processing requirements for cognitive tasks (in terms of tasks that require high degrees of attention capacity versus tasks that can be executed mindlessly), direction of attention (whether the attention was on the task or on the self), and timing of feedback are vitally critical to the impact of the feedback on learning.

Taylor et al. (2001) defined three key roles that capstone instructors take on to be successful design coaches: 1) a mentor providing support and showing the way, being there, aware, and helpful, 2) a mediator acting as a buffer between external reviewers and customers, and 3) a manager guiding the team in design decisions as well as team dynamics and communication. Marin et al. (1999) identified instructor mentorship as one of three key elements needed for successful capstone design experiences. Mentorship was defined as inspiring students to take ownership, fostering creative tension, and giving students the opportunity to fail as well as to succeed. Stanfill et al. (2010), in their proposed guide for capstone faculty mentors, identified the roles of faculty mentors as: a) ensuring that the team meets the goals of the course and b) keeping them focused on the project. Pembridge (2011) developed a mentoring model for capstone instructors based on their career and psychosocial developments, using the descriptions of instructors' mentoring practices. Mentoring for career development included preparing and promoting the protégé through exposure and visibility, coaching, protection and offering challenging assignments within the organization. Mentoring for psychosocial development, on the other hand, targeted protégé's sense of community, identity, and effectiveness in their role. However, the focus of Pembridge's research is on general behavior and perceptions of faculty as mentors or coaches, and it does not provide information about the feedback interventions needed to guide students' ideation skills.

In fields outside of engineering and industrial design, some research on feedback interventions in design has emerged. Communication scholars have investigated the culture of feedback structures and formats in design settings and the competencies observed in feedback sessions (Dannels, 2005; Dannels, Housley-Gaffney, & Martin, 2008; Dannels & Martin, 2008). Dannels and Martin (2008) described a typology of nine feedback types based on their ethnographic study of design studios as seen in Table 1.

Table 1. Feedback types (Dannels & Martin, 2008)

Feedback type	Definition
Judgment	Reacting to what they saw and rendering some assessment of its quality
Process-oriented	Criticizing student's design approach or process
Brainstorming	Proposing future imagined possibilities for the design
Interpretation	Trying to make sense of the concept or the product
Direct recommendation	Providing focused, purposeful, and specific feedback about a particular aspect of design
Investigation	Requesting more information about the design or the design process
Free association	Creating associations between the concepts with existing artifacts
Comparison	Comparing the design or the process with something else
Identity invoking	Suggesting that the students see themselves as designers in the future professional community

Feedback is understood differently by students at different education levels. Wilkin (1999) observed that students significantly varied in the way they utilized the feedback as a context for learning. For example, first year students said that they sought feedback to get the instructors interested in their work, to have a chance to gather more ideas, and to compare themselves with peers and confirm their positions as team members. Third year students primarily used feedback as a way to connect with an expert source with both technical and process knowledge and referred to feedback as a chance to test their ideas and assess others' ideas (Wilkin, 1999).

Many questions remain regarding what role instructor feedback has in idea generation, development, and selection, when and how instructors encourage students to be divergent or convergent with their ideas, and how feedback varies across diverse design disciplines.

3. Methods

This paper reports on a series of feedback sessions video-recorded between instructors and undergraduate students from three different disciplines: dance choreography (CH), industrial design (ID), and mechanical engineering (ME). The data were chosen from a larger dataset provided by the Design Thinking Research Symposia organizers. We chose these three diverse fields as a starting point to understand the nature of feedback interventions across disciplines. Our goals for the study were to investigate types of feedback related to concept generation, development, and selection, how these types of feedback suggested convergent and divergent ideation pathways for students, and how feedback types and related mode of thinking (convergent or divergent) mapped across the different design disciplines. Our work was guided by the following research questions:

> RQ1. What types of feedback do instructors provide for idea generation, development, and selection during feedback interventions?
> RQ2. How does feedback type direct ideation pathways for students?
> RQ3. What similarities and differences are evident in feedback across disciplines?

3.1 Participants and the Settings

Participants included two students in CH working individually on dance compositions, seven students in ID working individually, and fourteen students in ME split into three teams. The ID setting included an external client in addition to the course instructor providing feedback, whereas CH and ME only had their instructor(s) for feedback sessions. In each dataset, the projects' durations varied: CH - 4 months, ID - 2 months, and ME - 4.5 months.

Dance Choreography Dataset

For the choreography projects, students worked independently to design a dance piece for a public performance. The concept of the piece was student's own choosing, and this concept could be modified throughout the design work, as the piece took shape. Students created their own movement vocabulary and assembled the movement into a dance composition using choreography design tools. They were also required to select their performers, as well as manage sound, lighting, and costume design. They directed two rehearsals per week, and presented their works-in-progress at three separate company showings.

After these company showings, students participated in reviews, in which five dance instructors provided feedback on the dance work. In the first review, instructors provided feedback on the small sections of the students' work that they showed in which students were exploring the concepts guiding their composition and included an initial selection of music and costume. In the second review, the dance instructors responded to students' dance designs that combined small sections from the first review into a full dance work. The students were provided feedback on the synthesis of the dance elements into a full work and how the costume and music selections were aligned with the intentions and execution of the work. In the final review, instructors provided input on the full dance work presented by the students. All three of the review sessions for the two students participating were included in the analysis.

Industrial Design Dataset

The industrial design students worked on a sponsored project with an office furniture company that defined the project brief. The company was trying to bring a new line of impromptu seating units to the market, for individual office use and small meetings. They wanted the students to focus on bringing excitement into the office environment by approaching design concepts as accessories with color and emphasizing unique forms. Students were provided with design specifications, including shape, height, and size restrictions. It was important that the students' designs met the BIFMA testing criteria, which dictates a weight capacity of 253 pounds.

Students participated in five reviews throughout the project. In the first review, students met with the instructor for a desk critique, and were asked to decide on five concepts they would further develop. In the second review, students were asked to narrow down their concepts to three solutions to present to the client. In the client review, students presented their concepts to the client as well as the instructor, in front of their classmates. In addition to the instructor, students had the opportunity to gather feedback from the client. The fourth review focused on the evaluation of the full-scale prototypes of the chosen concepts, and in the final review, students presented both their appearance models and digital presentations of their solutions.

Mechanical Engineering Dataset

Three groups were formed to work on three different mechanical engineering design tasks. Based on some initial information, students were asked to develop their own problem definition and justify their reasons for its importance in engineering. The projects included designing: 1) an aquatic robot that can swim and move like a fish in order to follow real fish in the oceans and study them in their natural habitat, 2) a device that would safely open jars containing hazardous materials, and 3) a lever that tows aircraft out to a runway. Funding was provided for prototyping if the students developed their budget plans and got approval from their instructor.

In total, three reviews took place with an additional debrief. All reviews were conducted by the instructor in front of the class. In the preliminary review, student teams developed their problem definitions and initial design concepts; however, this review was not included in the dataset, thus our analysis focused on the second and third (final) reviews. The second review focused on reviewing prototypes and early evaluation findings. In the final design review, students showed their final designs and prototypes to the instructor and were immediately graded. While our analysis focused only on the second and final reviews, an additional review took place to choose one team out of three to move onto a design competition with nine other teams. At the end of the semester, students were also asked to reflect on their projects and the class in general and identify the issues they faced with during building their prototypes.

3.2 Data analysis

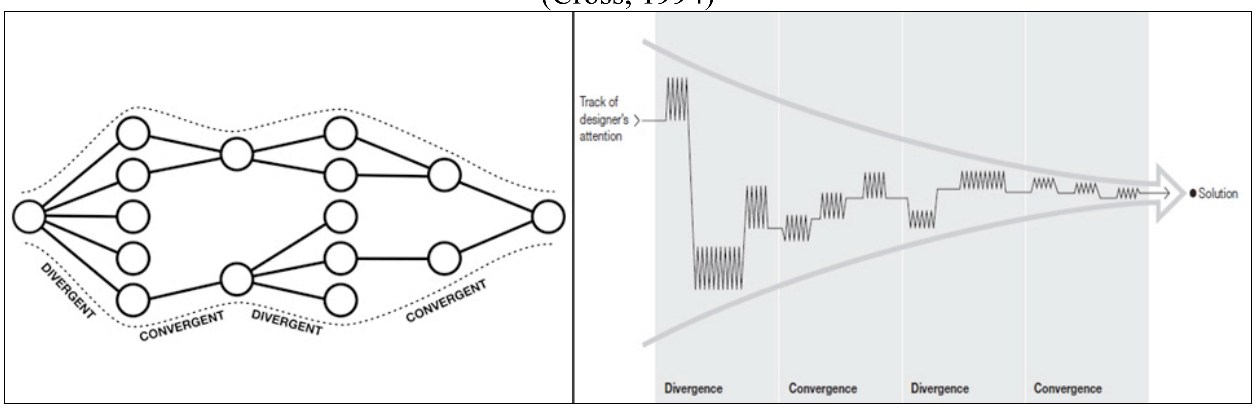
The purpose of our analysis was to characterize design feedback types evident across the three disciplines and examine how the feedback types guided the direction of students' concept generation, development, and selection processes. To determine the types of feedback in design critiques, we analyzed the entire data using a typological analysis framework that included processes of reducing the data, creating thematic categories, and drawing conclusions (Goetz & LeCompte, 1984; Miles & Huberman, 1994). The analysis process began with two coders, both seniors in Industrial Design, investigating the industrial design feedback sessions. They both took six project-based studio courses prior to their involvement in this research project, which allowed them understand the projects in-depth. To create thematic categories, they individually categorized a subset of data into similar types of feedback interventions using the constant comparison technique (Glaser & Strauss, 1967). After comparing each other's subsets, discussing and refining feedback categories' names, and generating operational definitions of each category, they individually coded a second subset and compared the coding results. This second round guided us to refine the category names and definitions. We then tried to extend the codes from the industrial design data to the dance choreography and mechanical engineering data. Codes were refined and added in response to incorporating these additional data. Then the first and second authors recoded the entire three sets of data with the refined coding scheme. The codes were then compared to those generated by Dannels and Martin (2008) to investigate how the emergent coding was compared to an existing typology.

We then analyzed how each type of feedback seemed to push on students' concept development process, i.e., was the instructor encouraging divergent thinking, convergent thinking, or thinking that was non-directional (neither convergent nor divergent)? While divergent and convergent thinking are complex, we developed our definitions to focus on a core idea of both types of thinking and to create a reliable approach to coding. We defined feedback as pushing toward divergent thinking if students were being encouraged to create choices for themselves. Feedback facilitating convergent thinking was defined as pushing students to make choices. Feedback that was neither convergent nor divergent was often asking students to develop their ideas without suggesting how that development should take place, i.e., whether students should create some options to consider and then decide, or to decide one way to achieve a particular goal and add it to the artifact. In many cases, there were times when a primarily convergent or divergent type of feedback could be considered non-directional or prompting the opposite kind of thinking;

however, in our coding of divergence and convergence, we made the decision based on primarily what kind of thinking was prompted. The codes were not intended to define an absolute way to view a type of feedback, but instead, to be able to determine if and how instructors encouraged both divergent and convergent thinking.

Design processes, overall, generally flow from divergent to convergent thought, thus we expected in the later reviews we would see greater pushes toward convergence. However, design process models represent smaller waves of divergent thinking throughout the process (Banathy, 1996; Cross, 2000) (See Figure 1). For example, in early design work, divergent thinking may be suggesting many diverse ideas, but in the mid to latter phases, divergent thinking may be suggesting multiple ways to achieve specific characteristics of the chosen concept. Even at the very last stages of design, decisions have to be made, and in those decision-making processes the possibility to be divergent exists by creating choices for how to accomplish final touches before the final choice is made.

Figure 1. Design process models
http://www.totemdevelopment.co.uk/blog/2009/10/innovation-using-the-peapod/
(Cross, 1994)



Additionally, because iteration is such a key component in successful design (Adams, 2002; Atman et al., 2007; Atman, Cardella, Turns, & Adams, 2005; Cross, 2000), at end of a design course, it is conceivable that an instructor could encourage students to think about what they would do if they had more time to iterate, e.g., where in their designs could they explore more options? Thus, while we expected the frequency and the amount of change to which divergent thinking suggestions would lead to decrease, our analysis included early, mid, and late design phase instances where instructors suggested divergent or convergent thinking as a way to improve design ideas and artifacts.

The last stage in our analysis included reviewing the coding for each of the disciplines separately to see what types of feedback were given most frequently and if the frequency of the feedback changed as the semester and student design processes progressed.

4. Findings

In this section, we describe the types of feedback on concept generation, development, and selection evident in the data (RQ1), discuss how the feedback type suggested convergent or divergent design thinking (or neither) (RQ2), and report on trends across disciplines, including how often certain types of feedback were seen in the data (RQ3).

4.1 Types of feedback and their relationship to convergent and divergent thinking

Our first goal was to characterize types of guidance provided for idea development during feedback interventions. Our analysis yielded various types of feedback given during the review sessions in each field, which we then compared to Dannels and Martin's existing typology (2008). In addition to characterizing types of feedback, we also analyzed if the feedback encouraged convergent or divergent thinking. In some cases, the type of feedback did not strictly encourage either type of thinking, or could facilitate both. Table 2 summarizes the types of feedback we characterized, and in the following section, we present examples from the three design domains and how the feedback promoted a certain type of thought.

TABLE 2. Feedback Characteristics

Feedback	**Description**	**Type of Design Thinking Encouraged**	**Disciplines in which this type of feedback was evident**
Direct Recommendation	Instructor tells students they should do a specific thing to improve their artifact.	Convergent	Dance, Engineering, Industrial Design
Draw Comparison	Instructor describes other existing artifacts or elements in nature that resemble student ideas.	Non-directional	Dance, Engineering, Industrial Design
Elaborate	Instructor has students consider aspects of their design that have previously been unspecified by providing details about mechanisms, materials and manufacturing technique to realize the concept in real life.	Non-directional	Dance, Engineering, Industrial Design
Evaluate Artifact Quality	Instructor gives opinion on the quality of student ideas.	Non-directional	Dance, Engineering, Industrial Design
Evaluate Progress	Instructor emphasizes the importance of time management and organization throughout the entirety of the project, and gives opinion on the progress and quality of student ideas.	Convergent	Dance, Engineering, Industrial Design
Interpret/ clarify	Instructor tries to clarify their interpretation of the design artifacts.	Convergent	Dance, Engineering, Industrial Design
Explore	Instructor suggests students consider multiple ways of achieving something that needs work.	Divergent	Dance, Industrial Design
Focus on Design Main Idea	Instructor keeps the students on track with suggesting focusing on the origin of the design.	Convergent	Dance, Industrial Design
Suggest multiple options to consider	Instructor suggests multiple ways the students might achieve a goal for a	Divergent	Dance, Industrial Design

	particular aspect of their design.		
Prototype/Test	Instructor suggests students prototype to better understand their options and evaluate if their idea(s) have potential.	Non-directional	Dance, Industrial Design
Assess Risk	Instructor evaluates or asks students to evaluate the consequences of the choices they are deciding among in terms of how safe or risky that choice would be.	Convergent	Industrial Design
Prioritize Ideas	Instructor suggests favorite ideas worthy of pursuit or asks students to evaluate which idea(s) to take forward.	Convergent	Industrial Design
Seek Inspiration	Instructor encourages students to seek external sources for new ideas.	Divergent	Industrial Design
Seek Simplicity	Instructor suggests minimizing the level of complexity.	Convergent	Industrial Design

From the table, it is evident that there are various types of feedback given by instructors during review sessions. The feedback itself varied in depth and level of specificity within each category. For instance, the ID instructor often told his students to keep their designs simple. In one example, he says: "Keep it simple. Keep it ergonomic". In another instance, he was more articulate in his guidance by saying: "It may be. It may be complex… And another thing we've gotta do one thing that would keep it simple like this, you know that simple geometry will be able to compress and – this, you still, you're gonna spend quite a bit of time 'cause you're trying to get multiple functions out of different angled geometry." Even though variations existed within feedback type, the message was consistent with regards to what the instructor was recommending.

The majority of instances of feedback were pushing students to converge rather than diverge (Table 2). The fact that there was encouragement for convergence was not a surprise; throughout the course of a project, students eventually have to arrive at an idea, and the time constraints of a project-based course often require that students move quickly into convergent phases. Additionally, as larger divergences usually occur at the early phases of a project, we did not capture early work of students due to data availability and the timing of feedback sessions. Likely, more divergence (and hopefully more divergent feedback) occurred during this time, but we did not capture this in our study. However, while an overall design process is convergent, design process models suggest multiple phases of divergence and convergence throughout, thus, we still expected to be able to see feedback suggesting divergence.

We also saw many relationships in the emergent feedback codes derived from our data and the feedback typology of Dannels and Martin (2008). Below, we present examples of each type of feedback, how the feedback encouraged divergence, convergence, or neither, compare the feedback to Dannels and Martin's typology, and discuss what the feedback looked like in different design disciplines.

Direct Recommendation

In this type of feedback, the instructor told students they should do a specific thing to improve their artifact. For example:

CH: “Is there any way that her foot could pop out over a person’s shoulder up here?”
ID: “You may want to at that front lower point maybe a bigger radius on that. Right at the bottom.”
ME: “You might want to think about moving the pivot point to the center of pressure so that moment arm is reduced.”

This type of feedback pushed toward convergent thinking, specifically that the student should determine how to make the specific change that the instructor suggested. This feedback type is similar to the ‘direct recommendation’ feedback type Dannels and Martin (2008) identified in their own dataset, where they described it as providing focused, purposeful, and specific feedback about a particular aspect of design.

Draw Comparison

Feedback interventions were coded as drawing comparisons when the instructor suggested existing objects or settings that were similar or different to students’ design ideas. Examples of this feedback included the following:

CH: “It reminds me of curlicue but it’s not, and there’s something like mother of pearl, like iridescent or something, about like the word, so I was very charmed by the word and how it relates to what you’re doing. So that’s really nice.”
ID: “Okay. You're still, depending on what your shape is, maybe your Hershey Kiss from the, from the front has a little bit more curvature, you know?”
ME: “So were we gonna finish the outside, paint it, make it look like a fish?”

The CH and ID instructors used both distant and close analogies (Christensen & Schunn, 2007), whereas the ME instructor primarily used close analogies as a means to understand or confirm the design.

This type of feedback was coded as a non-directional suggestion because most often the instructor did not seem to be suggesting changes to the design, rather trying to understand it. In the ID example above, the instructor did make a direct recommendation for change (a convergent feedback type), but in most of the cases of this code, the instructors were seeking clarity in understanding the decisions students had made. For example, the ID instructor often made comparisons that were not related to a design suggestion, but focused on understanding it. He commented that the student’s concept resembled tinker toys due to its modularity: “Kind of like tinker toys, sort of modular.” This feedback type is similar to Dannels and Martin’s (2008) ‘free association’ feedback type, defined as creating associations between the concepts with existing artifacts.

Elaborate

We coded this type of feedback intervention when the instructor prompted students to add more detail where decisions were not yet made. The instructors asked questions on aspects to include or eliminate, material choice, dimensions, mechanics, and the relationship of components to each other, manufacturing techniques, how the product/performance would be assembled or disassembled, force calculations, form modifications, CAD modeling, and cost Some examples include:

> CH: "I think you want to take each of your ideas, you know your panic, your sleep, um, and the caution and find out what the essence of each of those are you know like movement-wise and texture-wise, how to use time and space and all those cool things that you're already doing very well and you can maybe articulate your idea more that way by thinking about those elements, the essence of each of those ideas and then we'll see more you know distinguishing characteristics of that."
> ID: "Now this might be hard for them to manufacture- you have to think about that."
> ME: "Looking at that servo again… You might check that… with the relative position, and I realize the picture might not be accurate… But it looks like in an extreme location, I don't think it's going to work, but just check it to make sure."

The ID instructor focused on asking students to elaborate on the material choice and product dimensions and the CH instructors on movement vocabulary, space, and timing. The CH instructors emphasized the need to elaborate on the relationship of performers, (in design language, subcomponents) relative to one another, the manufacturing (or realization) of the final piece and the assembly and disassembly of the artifact/performance. The ME instructor focused on students making sure the idea would function and encouraged students to be specific on aspects of their designs.

All of the instructors often asked students to elaborate on the details of the concept they were pursuing. This happened through questioning, e.g., "Tell me about the materials. What are you thinking about on this?" and pointing out gaps in ideas, e.g., "I didn't understand her kind of a push – it was right before the two groups, lined up." This request for students to elaborate, or fill in missing details, was coded as neither pushing convergence nor divergence. Students needed to make a choice about the missing information. This could be done by thinking of one way to do it or multiple ways to do it and then making the decision. Thus, this feedback did not push divergent or convergent thinking primarily. It prompted students to make a decision, but their course to making a decision could be first to consider multiple possibilities and then pick the best option. This feedback type is similar to Dannels and Martin's (2008) feedback type 'investigation,' described as requesting more information about the design or the design process.

Evaluate Artifact Quality

This type of feedback was the instructors' judgments on what they liked and did not like about the artifact and what they thought was working and not working. The majority of the dance data focused on this type of feedback telling students the aspects of their dance works that were effective and ones where the instructor thought students should refine. For example: "I liked how just the duet went back and Rachel stayed out there by herself that surprised me." Also, "The one part of the whole piece that didn't fit for me was the foot, when the foot came out. It was funny to me, and it didn't fit with the rest of the piece for me, it didn't make sense."

In the ID data, the instructor often used evaluating as a means to lead the students to a certain direction and encourage them to further improve their concepts. His way of using this feedback was always supported with his rationale for why he liked certain concepts, and why he thought some concepts were not developed enough so they should be discarded. For example, "This is really fascinating, too, 'cause, again, it becomes a, a design element on its own, a, when you're not using it." "These actually may not be too stable."

In the ME feedback session, the instructor also practiced this behavior, focusing on if he believed the artifact would function as it should be based on students' design decisions. For example, "I got two concerns. One is the water tightness of the, ah, PVC. I think you need to make sure you got O-ring seals because you're gonna have to go in and out of that a number of times. … And so using RTB or, ah, silicone. Ah, it won't be too, ah, efficient for you if you have to pull it off… and then go in there and then reseal it and wait for it to dry and then pull it off."

This type of feedback did not seem to promote divergent or convergent thinking, but was focused on pointing out things that students should maintain in their design artifacts or change because the instructor did not think they worked. This feedback type is also similar to judgment Dannels and Martin (2008) have proposed where they explained this kind of feedback as reacting to what they saw and rendering some assessment of its quality. In our dataset, we observed many incidents where the instructors provided their opinions as they were assessing the concepts' quality.

Evaluate Progress

This type of feedback aimed to keep the students on track with regards to the schedule and expectations of the project, as well as to convey approval or disapproval their design progress. The instructor also specified how much time the students would need for certain activities to be accomplished in their design concepts. Examples included:

> CH: "You have to be done before Thanksgiving!"
> ID: "We have a limited amount of time. All right?"
> ME: "Why were we trying to get 'em last night as opposed to in the last three months?"

This feedback was straightforward, pushing students to focus on the end goal and finish their design artifacts. Evaluating student progress with a focus on the deadline pushed students to think convergently because the instructors wanted students to finish and get a working prototype. This code emerged from our dataset, but was not evident in Dannels and Martin's typology.

Interpret/ Clarify

Instructors asked for clarifying information to better understand the concept for the design. In the dance data, instructors also asked clarifying questions, primarily related to what the intention was of the student choreographer, so the instructors could decide how to help the student better convey the intention. For example: "I don't know if that was on purpose... I'm assuming your intention was the… scan."

In the ID data, both the clients and the instructor asked clarifying questions to the students, to understand the concept and what the students were considering regarding the details, such as materials. For example: "The piece that comes out, what did you envision the material was?" "you're saying that there's just separation between the layers of plastic for storage?" In addition to using this intervention for clarification purposes, the instructor seemed to use it to suggest the student to consider these questions as part of the decision making process. For example: "Just a metal cylinder?" "what if you were dealing with a two and a half inch by two and a half sections of upholstery?"

The ME instructor often used clarification questions either to understand the concept in detail or push the students to be aware of their decisions during the presentations. This was predominant in the engineering data, where students would present their concepts formally to the class and the instructor would ask for clarity to make sure he understood the details of students' concepts. For example: "How is that tail attached to the white – the white bar – the ABS?" and "Why do we do 90 degrees one way? Why, why are we doing that?"

This interpretation/ clarification feedback suggests convergent thinking, having student clearly articulate a choice and the reasoning for a decision. Similarly, Dannels and Martin's (2008) coding for interpretation was requesting more information about the design or the design process. In addition to using this feedback as a means to understand the concept better, instructors in our data set seemed to use it to question students' design decisions.

Explore

This type of feedback was evident when the instructor suggested that students consider multiple ways of achieving a particular goal of the artifact. The instructors did not indicate specifically how to achieve the goal, but suggested that students "play around" with ideas.

> CH: "So it's important but to… play around with that. [W]hat are they…feeling when they do that? Is it like some kind of thing they just do or is it – are they having a secret whatever your story is. "
> CH: "Play around with different hands, um, so what is it to you?"
> ID: "You could play around with the height of this thing"

This type of feedback suggested divergent thinking as the instructor told students they should think about possibilities that they could consider before making a single choice about how to achieve their goals. This feedback is similar to Dannels and Martin's (2008) brainstorming feedback type, where students are asked to consider future possibilities.

Focus on Design Main Idea

This feedback emphasized the idea behind the concept as a place to focus effort. In many cases, this feedback was used to keep the students on track with their initial goals and what was asked in the project brief. The instructors often asked the students to highlight the 'essence' of their concept, rather than including subcomponents that are not in alignment with the main idea or central problem. Some examples include:

> CH: "I don't get what that means so maybe a little more work on that. What is it to you? Is it subway? "
> ID: "So if you wanna keep the same design essence, but you have to make sure that it translate into what you feel excited about what made it nice."

The ID instructor seemed to use this feedback when his goal was to ask to students to follow their original ideas that they felt passionate about. It seemed he saw potential for them to stray by incorporating aspects not in line with their original intention or to moving away from that solution altogether, thus he prompted them keep focused on the concept as they originally intended. The CH instructors' approach was to support students in choosing design components, i.e., their compositional choices that were in line with the essence (the main idea) of the work. They suggested the students focus on the design origin by asking them the mood or feeling their performances would portray to the audience and how the design elements supported or hindered that main idea.

This type of thinking was coded as convergent, meaning as students focused on the main idea, they could choose one way to maintain the focus and stick with it. This code emerged from our dataset, but was not evident in Dannels and Martin's typology.

Suggest multiple options to consider

In some cases the instructor suggested multiple ways the students might achieve a goal for a particular aspect of their design. For example,

> CH: "I would play with timing or direction or placement of the stage space or other ways to, uh, surprise us…"
>
> ID: "Well, you know, again, there, you could even maybe, maybe this inner – the inner piece could be out of, ah done out of a different material. Who knows? Maybe that since it's small, and maybe it could be a bent plywood or something. I don't know – what I like about this is you could change it out to different – potentially, to [clears throat] other materials and different combinations of materials."

This type of feedback prompted divergent thinking with instructors giving students some ideas about where to start, and also modeling what different options could be. This type of feedback is similar to Dannels and Martin's brainstorming, as well as our own code, explore, but unique in that instructors gave students examples of the types of diverse ideas they could explore.

Prototype/ Test

We coded feedback in which the instructors suggested testing the design concept by conducting choreography experiments or prototyping in order to see whether the concept would function as the design student expected it to function. This feedback allowed the students to consider the roles of details within the bigger system, and be rather convergent with many design decisions to make. Some examples include:

> ID: "Well, play with it and you may want to, again, the foam models are gonna tell you a lot, but I would – yours are simple geometry, and looking at quarter scale. This exercise is getting your ergonomics correct."
>
> CH: "You might do like flock of bird exercises, what we used."

The ID instructor often asked the students to prototype their concepts physically to assess the ergonomics and usability of the concept in full scale. The CH instructors suggested exercises that would give the choreographers a feel for what the compositional choice would look like in the context of the piece as a whole or what kinds of emotions they would convey to the audience. In choreography, any consideration of ideas usually involves prototyping to some extent since choreographers will likely try it out on their dancers to see what something looks like. The language of prototyping was not used in the dance data, but the idea is central to the way design happens in this field. The ME instructor did not ask students to prototype during the feedback sessions; however, in the transcripts, we observed the students referring to their prototypes, indicating this was a part of their expected design work. The instructor did not indicate revisions or a need to go back to the prototypes during the data segments analyzed for this analysis.

We coded this feedback as non-directional because it seemed to be used in both ways across the data. If prototypes were to be used to validate an idea, i.e., a choice that was made, this is a prompt for further convergence. However, if a prototype was to be used as ways to consider possibilities, i.e., discover possibilities, this could be a prompt for divergence. This code emerged from our dataset, but was not evident in Dannels and Martin's typology.

Assess Risks

Instructors sometimes gave feedback that asked students to evaluate the risk of their design options, and encouraged students to make decisions to avoid these risks. For example:

> ID: "Cause you wanna do something kinda safe, and also they're bringing you in as a designer to, "what do you see in the future? You're the visionary."
>
> ID: "So we want to be able to get the biggest bang for the buck. And this is going to sell to more people and this is going to appeal to more people because it, it's got, it's got the different looks, but it's a simple form."

This feedback was observed in industrial design dataset. It pushed for a commitment to ideas that could work and would be done on time. It prompted convergent thinking because instructors seemed to be trying to protect their students from failure (not getting the project done on time, the function not working properly, poor form, etc.). Instructors wanted students to evaluate the risks of all of their ideas as well as the subcomponents of those ideas, and seemed to ask students to take a path that minimized these risks. This was a unique code that emerged from out data that was not evident in Dannels and Martin's work.

Prioritize Ideas

Instructors gave this feedback to try to help students narrow down their ideas. In some cases the instructor stated his/her preference and in other cases, the instructor asked the student designers to evaluate which would be their best option.

> ID: "Rate these in order of your, your preferences."
>
> ID: "Well, which would you rather develop? See this, this one is – this one is pretty far along. You gotta look at your materials."

This type of feedback was evident only in the ID data. This might be because this was the only situation where students still had multiple paths they could pursue, whereas in ME and CH, the students were developing one main idea. It pushed toward convergent thinking because the objective was always to narrow down the ideas and choose the concepts to pursue with based on a set of criteria. This was also a unique code that emerged from out data that was not evident in Dannels and Martin's work.

Seek Inspiration

This type of feedback prompted students to explore ways of accomplishing their goals by looking at how others have accomplished similar designs. When instructors encouraged this exploration, the implication is that students should consider multiple ways of accomplishing that particular goals and look externally to gather some ideas. For example:

> ID: "You gotta get online, look at how people are sitting in those things."

> ID: "This is a book of – you may wanna look at a purchase later. It's like these are well-known designers who come up with something really u-, unique and innovative, and they – then they – this just shows how they figured out how to make it, make it work in other words, how to build them."

This feedback was specific to ID, and it pushed for divergent explorations as the instructors suggested to students to think of other ways to achieve the goals of their projects, and gave students specific ways they could go about finding these other design options. For example, the ID instructor suggested to the students to get some inspiration from existing furniture to propose that there could be opportunities to explore how fun the concept could be: "But it needs to be, it, it, it has a great opportunity to be fun. That's why look at the Herman Miller and it, it's extreme, but I, I think with what true doing, like you could get some inspiration from it."

This feedback type had some similarities to comparison in Dannels and Martin's (2008) typology. However, instructors did not suggest students compare their solution to another solution; instead, they said for students look for other solutions, and see how that could guide their development of solution ideas.

Seek Simplicity

This feedback was only observed in the ID data. We coded feedback as seek simplicity when the instructor explicitly suggested simplifying the design or finding the essence of the solution, guiding the students to solve the 'real problem' in its simplistic way. Some examples of this kind of feedback include the following:

> ID: "Usually the simpler it is, the better, easier it's gonna be for the manufacturer, so it'll keep the cost down, which the manufacturers like that."
>
> ID: "This has got some really neat simplicities of design elements and form that, that's kinda – to me, that's a, that's a pure form. It's really intriguing."

The ID instructor often suggested that his students keep it simple. He used this feedback often, suggesting a key part of his approach was to direct students to focus on the real problem rather than creating additional problems and attempting to solve them. The ID instructor asked his students to convince the client with the simplistic solutions.

This feedback pushed the students to be more convergent since the objective was to simplify their conceptual solutions. The reason for the high frequency use of this feedback might be due to the fact that the students were required to build physical prototypes in a very short amount time. So, the instructor seemed to keep their concepts simple so that the students could fulfill the project requirements on time. This was unique to codes in Dannels and Martin's typology.

4.2 Similarities and Differences in Discipline-Specific Feedback

In this section, we discuss the feedback sessions as a whole within each discipline as well as the prominent types of feedback evident in the data.

The CH instructors all participated in the dance composition reviews as instructors as well as individual practitioners, who were choreographing their own works. They not only provided feedback for the students, but for each other, and students watched this feedback take place. This allowed students to witness that expert practitioners still engage in feedback to improve their compositions, and to hear the feedback given. The instructors' feedback focused on the qualities and consistency of the movement vocabulary throughout the dance piece, the use of compositional tools like space and timing, and how the various subcomponents of the work, including music and costumes, provoked an emotional response.

The most frequent feedback given by the dance choreography instructors was evaluating the quality of the artifact. The instructors discussed what they liked, i.e., what "worked" for them in viewing the composition, and what they did not like, i.e., what did not work for them about the dance and related elements. They also provided specific suggestions (direct recommendations) for how to fix what they perceived was not working but also suggested that students explore other ways to accomplish an aspect or suggested multiple ideas that students could explore (suggest multiple options to consider).

The ID instructor took a one-on-one mentoring role with the students offering suggestions and feedback throughout the entire process. The individual reviews allowed him to respond to many specific questions students had as well as to keep them on the task. His feedback focused on pushing the students make their own design decisions while presenting details on mechanics and materials that would be appropriate for each design. Emphasizing simplicity and continuing with designs that were considered 'safe' were his priority in his interactions with the students. Since the project was sponsored by an external client, the instructor constantly put the students in the client's mindset in terms of what would be feasible to manufacture and the appropriateness of the materials chosen. Convergent thinking and focus on the detail were critical in these feedback sessions, although the instructor helped the students make connections between their design solutions and existing artifacts and other designers' work.

In the ID data, the instructor often relied on the 'suggest multiple options to consider', 'direct recommendation', and 'elaborate' to push the students toward divergent thinking. In many cases, he used his expertise to explain how the student could solve an issue regarding a particular mechanism or what kind of material would be appropriate to use to manufacture the product. His approach was mostly to provide options for the student to consider, allow the student a chance to explore these options on their own and provide more elaborate ideas. He also often used 'elaborate artifact quality', 'elaborate progress', 'seek simplicity', and 'prioritize ideas'. These were feedback interventions that would lead to more convergent thinking as they all suggested the students to assess where they were, make decisions and simplify their solutions so that they could meet the deadlines and deliver the final outcomes on time.

The ME instructor asked clarification questions and probed students to justify their decisions. His influence in encouraging exploration may have taken place outside of design reviews, and design reviews were viewed more as professional presentations, and not spaces for feedback. The class seemed to be structured similar to an engineering business where the instructor was the project manager to make sure everything was working and each project was on schedule for final delivery.

Of the feedback evident during the student presentations, the most frequent type was interpretation, where students were asked to clarify aspects of their designs. Additionally, the instructor would provide direct recommendations if he thought an aspect of their design was not going to work.

The CH and ME projects required students to work from sub-assemblies to full-assemblies due to the complexity of the outcomes and design ingredients that had to work together with one another. ID projects differed since the students' approach was more holistic, creating their designs all at once. The CH instructors encouraged more divergence compared to the other instructors in ME and ID. The ID instructor used convergence and divergence in combination, and the ME instructor's approach was mostly towards encouraging the students to think more convergently. This is partly due to the lack of the idea initiation data from both ID and ME dataset, where divergent thinking feedback would be expected to be observed more frequently.

5. Discussion and Implications

Design education scholarship consistently points to the importance of critique, yet few studies conduct empirical and systematic analysis of feedback sessions (Dannels, Housley Gaffney, & Martin, 2011; Graham, 1999; Murphy, Ivarsson, & Lymer, 2012; Oh, Ishizaki, Gross, & Do, 2012; Stanfill et al., 2010). The results from our analysis expand on a set of feedback types by connecting them to modes of design thinking and comparing them across three design disciplines.

There were evident differences in feedback modes across our three datasets. The ID students received feedback in one-on-one feedback sessions, the ME students received feedback in team critiques in front of the class, and the CH students had round table conversations with their instructors where the instructors were also designing their own performances. The ID class had an external client so they were limited with the manufacturing processes and the materials available, the ME class was preparing for a competition where only one successful team would win and where only the functional prototypes would be presented, and the CH class was preparing for a public performance. The differences we observed in each of the design reviews could be a function of the discipline, but could also be a function the design problem on which students were working, the course structure, and constraints and resources of the course. These contextual differences likely prompted variations in type of feedback and feedback approach.

While there were some distinctions in feedback culture, also evidenced in the work by Lande and Oplinger (2014) and Goldschmidt et al., (2014), there were many similarities in the ways instructors guided their students. Overall, feedback recommending convergent thinking was more prominent than feedback recommending divergent thinking. It seems a key role the instructors viewed themselves as having was assisting students in clarifying details, making decisions, and completing their work on time rather than pushing students to investigate further possibilities for alternative solutions. Even though these are important components for any design, one important question that emerged from our work is when there is room to pursue a risky idea. Instructors did not tend to encourage students to abandon ideas they had or to go back to the drawing board and think of all of the different ways they could do something. In many instances, the realization of ideas was prioritized over searching deeper for 'better' solutions for the same design problems.

As the cases we analyzed did not capture project initiations, in which divergence often is the main goal, we are not claiming that instructors rarely encourage their students to diverge.

Instead, what our analysis revealed is that the instructors in these cases rarely encouraged divergence throughout the mid to latter stages of design. While divergence is fundamental to early design stages, it can have an important role in mid to later phrases; the amount of divergence likely changes, but there are benefits to later-design phrase explorations. Banathy's (1996) design process model illustrated such an iterative process where the nature of the design process was described as repeated steps of divergence and convergence, and analysis and synthesis. The same iterations throughout the entire design process were characterized by Cross (1994) as divergent and convergent cycles. Cardella et al. (2014) emphasized the importance of both reducing and maintaining ambiguity throughout design work, which is consistent with the necessity for convergent thinking to bring clarity to an idea and determine details as well as the necessity for divergent thinking to generate multiple options for consideration.

While we recognize that design is overall a convergent process, and that course constraints support convergent thinking, our analysis prompted us to consider how instructors could also help students think divergently throughout their design experiences. For example, an instructor could have said, "What are five different materials you could consider here?" or "What are the other ways for the user to push?" Within areas that need convergence, do instructors ensure that students have first thought divergently? From our dataset this is unclear; it did not occur during the context of the reviews, but perhaps it occurred as part of the classroom instruction or assignments. Regardless, it appears that most feedback during review sessions are encouraging idea convergence, rather than using divergent thinking to explore more possibilities. Additionally, we noticed some of the convergent feedback supporting a minimization of risk of failure. It is important for students to have design successes; however, one question that emerged from our findings was when the instructors encourage students to take risks. In these data sets, there were not occasions where instructors pushed students to think more divergently into "unsafe" territory, in which the consequences might be a design failure. Divergence is not equivalent to risk-taking nor does divergent thinking leads to design failure, but divergent thinking promotes exploring unchartered idea territories, which takes time, and has risks associated with it.

There was evidence of feedback prompting divergent thinking. This came in the form of instructors suggesting students explore ways they could accomplish an idea or suggesting multiple options for students to consider. However, we did not find any general feedback in which instructors asked students if they had fully explored their options, whether for their overall concept or components of their ideas. They pointed to places where students needed to make decisions, but did not ask if students had given themselves enough options to decide among. Again, we cannot say this did not happen in the course as a whole, but there was no evidence of this happening during feedback sessions.

We also noticed that feedback given allowed students to take either a convergent or divergent approach moving forward. In the dance domain, instructors gave their personal emotional responses to the designed dance composition; from that feedback, students could either decide they needed to converge on some aspects to further support or change the emotional response of the instructor, or they could decide they needed to explore some additional ideas in order to get the emotional response they were seeking. Adams et al. (2014) called this strategy 'let the student figure it out' which involved instructors encouraging students to make their own decisions. This type of non-directional feedback was fairly common across the design instructors in our data set. It seems that in some cases instructors were trying to point out areas that needed to be addressed, but did not push with regards to how to address it to allow students to determine their own approaches.

As another example, instructors encouraged prototyping as a way for students to get a better indication of how well their idea would work and where there were areas they needed to address. Based on the prototyping, students could either diverge and consider more options or converge by choosing the one that worked best or clarifying realized gaps. Some instances pointed students more toward decision-making and some more toward exploration of how to achieve something in their designs. McNair, Paretti, and Groen (2014) found that the quality of artifacts involved in the feedback sessions played a critical role in both deciding the kinds of product features to be discussed, and how they would be discussed. A question for further pursuit is if there is a relationship between the quality of artifact presented and the instructors' suggestion for divergence or convergence in the idea development pathway.

Instructors also gave general feedback indicating whether they thought students were on the right track or needed to do a better job with their design work. Such evaluative feedback included comments like: "It's pretty neat," or "You're approaching a point of what we don't have much that you're delivering." Although this type of feedback helps students to understand whether they should follow the ideation path they were on, or whether they have to diverge from it, this type feedback was often not specific enough to lead the student in either direction.

Future research should address our three research questions in greater depth, with a specific lens on how these feedback types impact students' designs and processes. For this analysis, we only investigated the conversations among the instructors and the students; however, a deeper analysis is needed to examine the students' outcomes and how they alter after each feedback provided by the instructors. Specifically, such research could help us better understand how students respond to the different types of feedback and those responses might create alterations in their design processes. Future research should also explore how the feedback varies for each step in the design process, and whether there are specific feedback interventions that are offered in the earlier versus later stages of the design. Furthermore, future research could also explore the feedback types that emerged in this analysis with larger pools of design courses (from freshman to graduate), design disciplines, and reviews.

6. Conclusions

Feedback in design courses help to shape the developmental, relational, and educational pathways of the discipline (Dannels & Martin, 2008). But how many of us consider feedback this seriously when we provide it to our students? How aware are design educators of their feedback pushing students towards convergence or divergence? From this analysis, we have a glimpse at the types of feedback that were commonly used to direct design thinking across three design disciplines. Our findings can help us, as instructors, to be more reflective and purposeful about the feedback we give, and how that feedback could support or hinder innovative ideation pathways. Both convergent and divergent thinking are necessary to creativity, idea development, and design success, thus engaging students in both types of thinking multiple times throughout their work is critical.

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