2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33745

Evaluating Peer-led Feedback in Asynchronous Design Critiques: A Question-centered Approach

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Abstract

Design critiques are a central component of the design studio. In engineering education, where the design studio pedagogy is becoming increasingly popular, peer-led critiques can play an important role to support and complement the feedback student teams receive from instructors and clients. In capstone design courses, peer critiques are typically delivered in face-to-face, synchronous environments, where students can demo their design progress and engage in constructive back-and-forth discussion with their peers. The disruption due to the COVID-19 pandemic, which has caused many design courses to be held remotely, has forced instructors to re-imagine how peer critique can be delivered in a virtual, mostly asynchronous setting.

In this paper, we describe and evaluate an asynchronous and virtual implementation of peer critiques that are delivered using a text-based discussion forum. Taking a question-asking lens, we analyze hundreds of questions posed by students in asynchronous peer critiques of a capstone design course, and compare the distributions of low-level, deep reasoning, and generative design questions to results of prior studies that have produced analogous distributions in conventional face-to-face settings. We find that a larger portion of peer inquiry that is delivered in written form in asynchronous critiques is composed of generative design questions, which serve to expand the design space, and which have been previously found to be highly valued by design teams. Our findings serve to not only evaluate the effectiveness of the written, asynchronous approach to design critiques, but also support a discussion on how some of its features can be useful even when in-person peer design critiques are feasible.

1. Introduction

Design critiques are an effective design pedagogy in which students engage in conversations with instructors and peers to facilitate improvement of design solutions. Feedback-giving is essential to conversations established within design critiques, often taking the form of questions that further challenge and improve the projects under review.

The COVID-19 pandemic has shifted many interactions to online environments. Design critiques that traditionally have been conducted face-to-face have been forced to transition to a virtual format. Question-asking is a particularly useful perspective in which to evaluate design critiques, even within a virtual, asynchronous environment. Thus, using a question-asking lens, this paper aims to evaluate the effectiveness of virtual peer-led design critiques and to compare them to the traditional face-to-face implementation.

The remainder of the paper is organized as follows. We begin in section 2 with an overview of previous research on design critiques, with a focus on feedback and question-asking in engineering design education research. Section 3 presents our research approach, and section 4 presents the results of our analysis and an evaluation of virtual peer-led feedback in comparison to in-person implementations. In section 5, we discuss the implications of this study for design

pedagogy, and present limitations and future research directions. Section 6 concludes the paper with a summary of our findings.

2. Background

2.1 Design critiques

The design studio has long been a central pedological tool in many design disciplines. It provides a multifaceted environment within which immediate feedback can be provided to the designer and their work can be assessed [1]. In practice, the studio promotes a learning-by-doing atmosphere in which instructors offer formative feedback on students' design work on a weekly basis [2], [3].

A dominant feature of the design studio pedagogy are design critiques (or design crits), serving as milestones in which students receive formative feedback and guidance from tutors on their design work [4]. Design critiques stem from the mentor-apprentice relationship of working and learning, and leverage experiential learning principles [5]. Here, tutors evaluate students' projects, reframing the design problem space, and recommending possible solutions to address these problems [4]. Design crits are common across many disciplines, including architectural design, graphic design, and industrial design, providing a platform from which instructors can assess the work and design ability of their students [6]. In the field of architecture, students communicate regularly with their peers and instructors, to reflect upon their design work [7]. Interactions between students and their instructors and peers can range from informal discussions that focus on constructive feedback, or more formal discussions that are evaluative in nature [8].

In the context of engineering education, the primary pedagogical tool are design review meetings, which function similarly to design crits. They serve as a learning space where students present the progress of their project, with a focus on receiving (typically) summative feedback that evaluates the design outcomes of their work [9]. While traditionally this feedback is provided by the instructor and/or project client, recent implementations have more heavily relied on peer involvement. Students participate in inter-team assessments of oral presentations, as well as other facets of the design process, including assessment of prototypes and the efficacy of design decisions [10]. In these feedback sessions, student teams meet with peers or external experts at regular time intervals to discuss the status of their project and receive feedback [11], [12]. This community-based interaction is characteristic of the pedagogical transformation in design education towards a design studio environment evolving from traditional mentor-apprentice relationships [2].

Significant prior research has explored the role peer feedback plays in student learning. Cho and MacArthur [13] found that peer feedback provided by multiple peers was more effective in improving students' writing performance than feedback provided by a single expert, or a single peer reviewer. Although some students held negative perceptions of the fairness and reliability of receiving feedback from peers, they derived benefits from participating in peer assessment, exemplifying a higher degree of reflection and more effective revisions of their own work [14]. More recently, studies have investigated the role of peer feedback in design reviews/critiques in engineering courses. For example, Cardoso et al. [9] found that high-performing teams provide

more and better feedback to their peers, a finding that is consistent with Li et al. [15]. Similarly, Thiam et al. [16] and Madruga et al. [17] explored the relationship between perceived feedback quality and its quantity and nature. The researchers note that there is a slight decrease in quality as more feedback is provided, and that students found positive, but critical feedback to be more meaningful. The involvement of peers in review activities where feedback is exchanged has become more prevalent within the realm of engineering design education to foster an increasingly collaborative environment that facilitates student learning [1], [18]. The feedback students receive can be further prioritized and adapted to actionable items that can be improved upon for future design milestones.

2.2 Feedback and question-asking in design critiques/reviews

Central to design critiques/reviews is the acquisition and provision of formative feedback, defined by Shute [19, p. 154] as "*information communicated to the learner that is intended to modify his or her thinking or behaviour for the purpose of improving learning*". Thus, the reciprocal nature of providing and receiving feedback may enhance the iterative process of design, by allowing for the given design work to be continuously improved upon and transformed towards a more refined state.

A number of studies have investigated the role of feedback in design critiques. For example, in an analysis of feedback in design critiques within the fields of dance, industrial engineering, and mechanical engineering, Yilmaz and Daly [20] found that feedback given to students from their instructors facilitated more convergent thinking, as opposed to divergent thinking. A typology of feedback statements proposed by Hurst and Nespoli [21], [22] decomposes feedback into two distinct dimensions of topic and function. The topic dimension identifies the specific area of focus surrounding the given feedback statements, including design, management, and communication of the project. The function dimension aims to explain the specific intention that the feedback statements serve, whether that be for comprehension, evaluation, or recommendation of a future direction. Regardless of their topic or function they fulfill, feedback statements often take the form of *questions*.

In this study, the primary lens from which we explore peer question-asking within design critiques/reviews is through a question-driven design thinking model proposed by Eris [23]. The model extends upon previous research by Lehnert [24] and Graesser and McMahen [25], in which three classes of questions important to design activity are identified. Question-asking is a fundamental mechanism to promote design thinking in design critiques [26]. Questions received can encourage two distinct pathways of thinking: convergent and divergent [23]. According to the taxonomy proposed by Eris [23], questions are classified according to 22 specific categories, which fall under three broad classes:

- *Low-level questions (LLQ)* are asked to attain clarification on information related to gaps in the design project, or its processes, during communication. This class of questions can be further divided into eight subcategories that include verification, disjunctive, definition, example, feature specification, concept completion, quantification, and comparison. Inquiry within this class evokes convergent thinking in which the answer is known and can be recalled by the respondent. Questions under this class can be useful for

referencing specific components of the design process that have been completed, or clarifying missing information related to the design content [12].

- *Deep Reasoning Questions (DRQ)* aim to generate causal explanations that describe the phenomenon under focus. They can be further divided into the subcategories of interpretation, goal orientation, causal antecedent, causal consequence, expectational, procedural, enablement and judgemental. Similar to low-level questions, questions asked under this class encourage convergent thinking, whereby an answer is retrieved by the respondent based on pre-existing information that the respondent believes to be true.
- *Generative Design Questions (GDQ)* aim to facilitate the generation of many possible answers, regardless of whether they may be perceived as true/feasible or not. Subcategories under this class include: proposal/negotiation, method generation, scenario creation, ideation and enablement. This line of inquiry, prompting divergent thinking, encourages the respondent to assess possible answers, and identify specific ones that satisfy a given criteria. This process of investigation, comparison, and evaluation, as noted by Eris [23], comprises an essential element of design cognition that also coincides with the iterative process of design activity.

DRQ and GDQ are considered high-level questions. In contrast to LLQ, both classes of questions necessitate the accomplishment of higher-level objectives in accordance with Bloom's taxonomy of educational objectives [27]. GDQ, in particular, operate within the concept domain [28], involving evaluation that coincides with the highest achievable level of Bloom's taxonomy. However, LLQ still remain integral to the formation of baseline understandings of the design process being undertaken, or the purpose of particular aspects of design content. It is from LLQ that comprehension of the given design project is established, which effectively advances discussions during design critiques towards the introduction of high-level questions.

2.3 Feedback and question-asking in virtual design critiques/reviews

Due to the COVID-19 pandemic, the teaching of engineering courses, including engineering design, has shifted to virtual environments to accommodate the transition to online learning. This shift also extends to the design studio, with virtual design studios involving design activity that takes place remotely through virtual collaboration platforms. Design critiques delivered in an online format have been found to increase student engagement and encourage design thinking [29]. However, not all virtual environments are conducive to the exploratory and generative purpose of a design critique. In a study investigating design behaviour across different environments, Maher et al. [30] found that during collaborative architectural design activity in a face-to-face studio environment, more focus was placed on engaging in design discourse to generate ideas and develop a solution, compared to working in a 3D virtual environment, where designers spent more time modelling their design.

The implementation of a virtual design studio can be an innovative augmentation of the physical studio that impacts peer communication and engagement. The focus on student-centric interactions through asynchronous tools within these virtual environments can expose students to a variety of perspectives outside of the tutor in a conventional studio [31]. It is thus important to distinguish how peer-led critiques are affected by the change to a virtual and asynchronous learning space.

3. Methods

3.1 Case study

We performed this present study in a 12-week management engineering capstone design course that was held virtually in the Spring 2020 term, due to the COVID-19 pandemic. In the course, 17 student teams comprising of 3-5 students each, were divided into three clusters. Each cluster of teams participated in two rounds of peer project review (PPR). The purpose of PPRs was to provide teams with the opportunity to present their design project and progress, and receive constructive feedback from peers, supplemented by feedback from the instructional team, to improve upon their work. Further, the PPRs were an excellent opportunity for students to advance their abilities in giving constructive feedback.

The first round of reviews (PPR 1) took place at the beginning of the course (week 4), while the second (PPR 2) took place near the end (week 10). During the respective weeks, teams posted an update on the status of their project to an online discussion board by starting a discussion thread. This update typically included a set of presentation slides and an updated draft of the project report. Sometimes teams asked their peers for feedback on specific aspect of the project, but generally, peers were encouraged to provide feedback on any and all components of the update. Students from each team had the following week (week 5 and week 11 for PPR 1 and PPR 2, respectively) to review the posts presented by other teams within their cluster and provide feedback to at least two teams by posting a reply under the appropriate discussion thread. In addition to students, the instructor and teaching assistants also replied to student teams' threads with feedback that was included in the data set. The importance of peer critiques was emphasized to the class at the beginning of the term. The instructor explained the role that reflection plays in design and how question-asking can facilitate that reflection [9].

3.2 Data collection

Data was collected from only one of the three clusters, comprising of 6 of the 17 teams that participated in the two PPRs. There were two reasons for this. First, the discussion posts posed across these 6 teams generated a significant breadth of feedback for our analysis. Second, projects were assigned to cluster depending on their theme, and the theme of the cluster chosen for analysis more closely resembled the theme of a cluster that was previously analyzed in [9], which enabled better comparison across studies.

Over the two PPRs, a total of 385 questions were extracted from the discussion board posts posed by students and teaching staff. Each response was independently coded by two coders using Eris' [23] question-asking taxonomy, as presented in Section 2.2. In particular, each question was assigned a question category under one of three broader classes:

- LLQ class: *verification* (Ver), *disjunctive* (Dis), *concept completion* (Con), *feature specification* (FS), *quantification* (Qnt), *definition* (Def), *example* (Ex), *comparison* (Com), *and interpretation* (Int)

- DRQ class: *rationale/function* (RF), *causal antecedent* (CA), *causal consequent* (CC), *expectational* (Exp), *procedural* (Pro), *enablement 1* (En1)
- GDQ class: *proposal/negotiation* (P/N), *scenario creation* (SC), *ideation* (Ide), *method generation* (MG), *enablement 2* (En2)

Subsequently, both coders participated in an arbitration session for the purpose of resolving any conflict between the assigned codes. The inter-rater reliability was computed using Cohen's Kappa, and was found to be moderate (k = 0.49) when considering the categorization of the extracted questions at the higher level of the three distinct question classes (LLQ, DRQ, GDQ). The overall level of agreement between both coders on the specific question categories within each of the broader classes was also moderate (k = 0.41).

4. Results

4.1 Descriptive analysis

As shown in Figure 1, of the 385 questions comprised in the feedback utterances, 153 (40%) of the questions asked were LLQ, 57 (15%) were DRQ, and 175 (45%) were GDQ. The most prevalent question categories were verification, disjunctive, and concept completion under the LLQ class; procedural and judgemental in the DRQ class, and proposal/negotiation and method generation in the GDQ class.

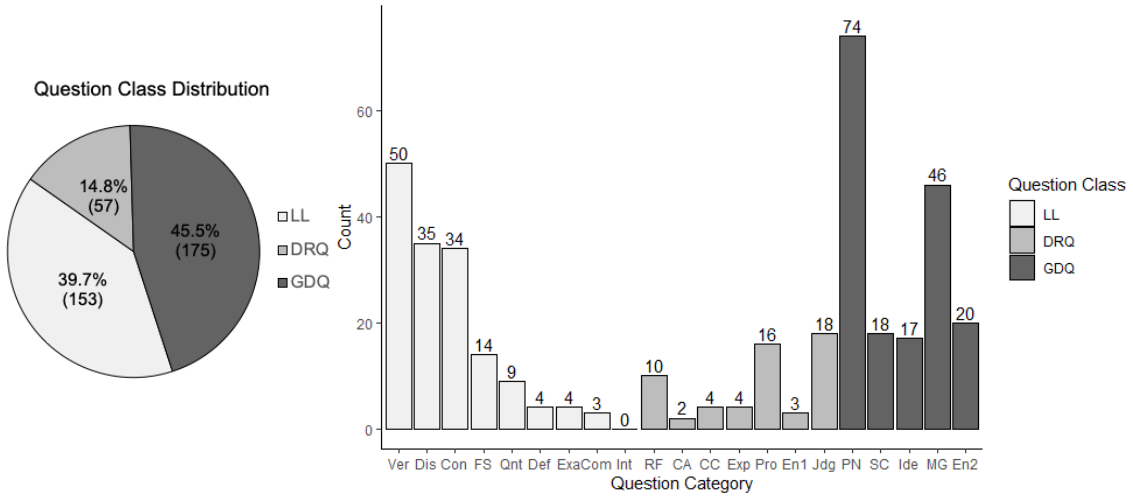

Figure 1 Distribution of questions across broader classes (left) and categories (right)

We also consider the distribution of questions across each of the two PPRs (Figure 2). We first note that the total number of questions asked is significantly smaller in PPR2 (136) compared to PPR1 (249). A likely explanation for the difference is that PPR1 was the first opportunity for students to learn about their peers' projects. Despite the difference in volume, overall, the distributions of questions according to the question classes appear to be similar: during PPR1 and PPR2, respectively, 101 (41%) and 52 (38%) of the questions asked were LLQ, 38 (15%) and 19 (14%) were DRQ, and 110 (44%) and 65 (48%) were GDQ.

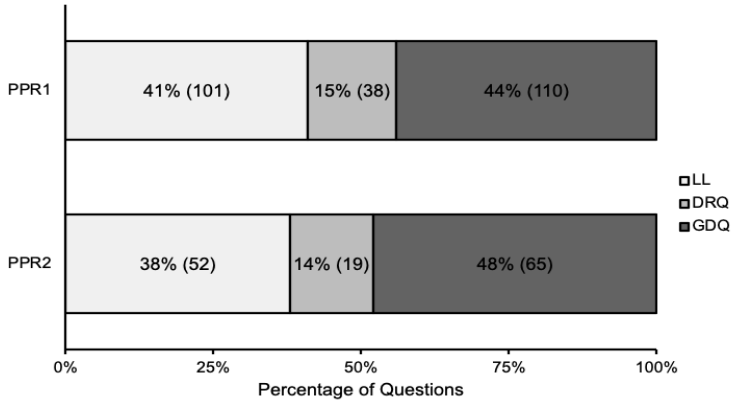

Figure 2 Distribution of questions in PPR 1 and PPR 2

From the 385 total questions identified from both PPRs, 360 originated from student peers, and 25 originated from the teaching staff, involving the instructor and one teaching assistant, hereon referred to collectively as advisors. We find that the distribution of questions is broadly similar for students and advisors. As depicted in Figure 3, when examining the distribution of questions posed by students and advisors, separately, across the two PPRs, we found that the most common questions asked by both students and advisors were GDQ (45% and 56%, of student and advisor peer feedback, respectively). LLQ made up 40% of the students' questions, compared to 32% of the advisors' questions. Finally, DRQ were the most infrequent for both students and advisors (15% and 12% of total questions, respectively).

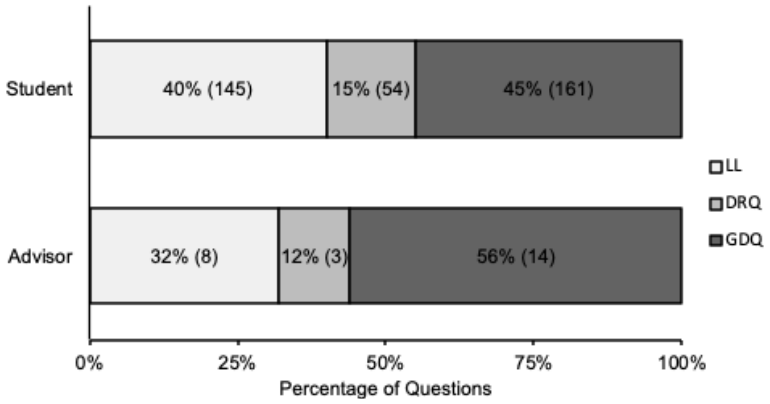

Figure 3 Distribution of questions originating from peers and advisors

4.2 Comparison to face-to-face implementation

In what follows, we consider how student and instructor peer feedback may be affected by the virtual delivery of the course, and in particular, by the written, asynchronous nature of the delivery of feedback. Two prior studies by Cardoso et al. [9] and Hurst and Nespoli [22], which were conducted with similar student cohorts completing analogous peer-led face-to-face design critiques, provide a useful benchmark for comparison. In the settings investigated by these two previous studies, student teams first presented an update on their project progress and then

answered questions from peers. A total of 309 student-originated questions were analyzed by Cardoso et al. [9], whereas 553 questions were analyzed by Hurst and Nespoli [22], of which 298 questions originated from students, and 255 questions originated from the instructor.

We first compare the overall distribution of questions in two settings (Table 1): face-to-face implementations of peer review [9], [22] and the virtual implementation described in this case study. We note that a similar portion of questions posed to design teams are of the DRQ type: 11% and 19% in the two in-person implementations, and 15% in the virtual implementations. Large differences are however observed in the other two question types. First, we note that the virtual implementation leads to a lower portion of questions in the LLQ class. While in the in-person delivery most questions were LLQ (68% and 70% in Hurst and Nespoli [22] and Cardoso et al. [9], respectively), in the virtual delivery, LLQ comprise just 40% of the total. In contrast, a larger portion of questions posed in the virtual delivery fall in the GDQ class (45%) compared to a smaller proportion (11% - 21%) recorded in in-person deliveries.

Table 1 Distribution of questions across question categories in different delivery settings

	LLQ	**DRQ**	**GDQ**
In-person, synchronous, verbal			
Hurst and Nespoli [22]	68%	11%	21%
Cardoso et al. [9]	70%	19%	11%
Virtual, asynchronous, written	40%	15%	45%

Focusing on the involvement of student and teaching staff in the provision of feedback to design teams, we further investigate differences by considering questions originating by students and the teaching staff, separately (Table 2). We find that the patterns described above hold for both student peers and teaching staff. For both sources, we observe an increase in the proportion of GDQ. This is largely at the expense of a significant decrease in LLQ. The proportion of DRQ remains largely unchanged in the two modes, for both student peers and teaching staff.

Table 2 Distribution of questions across question categories by source and delivery mode

	Peer			**Teaching staff**		
	LLQ	**DRQ**	**GDQ**	**LLQ**	**DRQ**	**GDQ**
In-person, synchronous, verbal						
Hurst and Nespoli [22]	65%	12%	23%	74%	10%	16%
Cardoso et al. [9]	70%	19%	11%	N/A	N/A	N/A
Virtual, asynchronous, written	40%	15%	45%	32%	12%	56%

5. Discussion

5.1 Summary of findings and implications

In this study we have taken a question-asking lens to examine the nature of peer feedback in virtual and asynchronous design critiques in a capstone engineering design course. Previous

analogous studies completed with similar student cohorts ([9] and [22]) allowed us to qualitatively compare the feedback in a virtual setting with that produced in regular in-person and synchronous critiques. Our findings suggest that the virtual implementation of peer-led design critiques results in an increased frequency of high-level questions (in particular GDQ) and a reduced frequency of low-level (clarification) questions.

A significant difference in the two modes of feedback delivery is that in the in-person, synchronous implementations, the feedback was provided verbally, whereas in the virtual, asynchronous implementation described in this study, the feedback was provided in written form as entries in a discussion forum. Prior studies suggest that written peer feedback is more elaborative and provides more information than verbal feedback [32]. Our findings also point at a similar pattern; given that design teams value high-level questions most [9], it follows that the written feedback peers have provided is likely of higher quality than the feedback they may have provided verbally, if the critiques had been held in person.

Considering the changes to the delivery of design courses caused by the COVID-19 pandemic, peer critiques carried out virtually through written communication remain resilient and can function as a reliable tool for learning and assessment. The increased prevalence of proposal/negotiation questions, in particular, demonstrates the useful collaborative environment that is facilitated by virtual peer review. These questions aim to expand the solution space, and challenge students to consider new perspectives to improve their design work. Having students and the instructional team communicate through written feedback encourages them to exchange opinions with the design teams, and may support more elaborate feedback-giving that introduces the possibility of new ideas to the solution space. Facilitating peer reviews through an asynchronous mode of delivery thus provides more time for reflection that is essential to the formation of higher-level questions.

A direct implication of these findings is that peer review activity can benefit from the inclusion of written peer feedback in conjunction with face-to-face, verbal feedback. That is, even when in-person design critiques are again possible, the pedagogical design should allow for opportunities for written feedback. In these written submissions, student peers would be invited to reflect more deeply on their peers' designs and perhaps expand and add on to feedback provided during in-person reviews, where most questions asked are typically low-level, clarification questions [9], [22]. This promotes divergent thinking that can be instrumental to student learning and complement the verbal feedback provided in the face-to-face implementation.

5.2 Limitations

While the comparison between the distribution of questions in our case study and prior distributions reported in Hurst and Nespoli [22] and Cardoso et al. [9] provided useful insights, we also recognize the limitations of such a comparison. The comparison was between- and not within-group; as such, the variation in results may be attributed to the differences in the samples, and not in the mode of delivery of feedback. In addition, the projects were not controlled in this study, and thus, the variation among the work presented by each design team may influence the quantity, and type of feedback received. We tried to reduce the impact of this limitation by

choosing students from the same program belonging to different years, and only studying feedback from teams belonging to similar project types.

A caveat of our sample size should also be considered. For this study, we only analyzed a subset of feedback statements from one cluster of 6 teams, based on subjective interpretation of the high quality and comprehensiveness of their feedback over the two rounds of peer review. Thus, a general limitation of our study is its small sample size, which did not provide us with a large enough dataset to complete a statistical comparison between student and instructor-given feedback. Nevertheless, even though the feedback statements were collected within a small, specific context, the quantity of the feedback statements generated was quite substantial and authentic to a virtual implementation of peer review.

5.3 Future work

This study builds a basis for future work to explore different approaches that can improve the conventional peer review process. Future work can investigate the possible moderators or mediators associated with peer review activity. It is plausible that written feedback could be considered more formal, compared to verbal feedback provided in a face-to-face setting, influencing the quantity and type of feedback received. The time taken to develop feedback in both a virtual and in-person approach to peer critiques should also be examined. Further examining this temporal component could be useful for instructors to assess how more efficient and effective peer review sessions can be implemented in course delivery.

Future work can examine the joint implementation of verbal and written feedback, to further investigate the influence of both communication channels on the content of the feedback generated. In this study, comparisons between student and instructor feedback were made across two prior studies, where students worked together in teams, and the exchange of feedback occurred among other teams, in addition to the instructor. Subsequent research could also explore more formal and structured comparisons among instructor and student feedback during peer review activity. Given that both groups provide feedback independently from one another in the context of virtual peer review, the feedback may differ in quantity and type from an in-person, face-to-face setting, where both groups exchange feedback in the presence of one another.

Although our findings suggest that written feedback provided during peer critiques is more generative than verbal feedback, these findings are not definitive. For example, Carberry et al. [33] found that students' verbal feedback provided more elaborative peer critiques than written feedback during a web-based implementation of peer review, where audio recordings were used to facilitate verbal feedback. Thus, future studies should consider the varied approaches in the provision of verbal and written feedback in the delivery of peer critiques that can influence the quality of the feedback.

6. Conclusions

Our study contributes to research on the role of inquiry during peer-led design critiques. We analyzed questions posed by students during asynchronous peer-led critiques and presented

findings that provide insight into the type of peer feedback given in a virtual learning environment, where project critiques are provided in writing. Our findings highlight that, overall, the majority of questions asked were generative, a class of questions that prior studies have found to be highly valued by the receiver . Questions under this class were also the most common in the feedback gathered when considering the distribution of the questions across both peer critique sessions, and across questions posed by students and instructors, individually. The high frequency of generative design questions is particularly meaningful when compared to two analogous studies of peer critiques within a conventional face-to-face setting, in which low-level questions were more prevalent. These findings overall support written, asynchronous design critiques as a useful mode for enhancing exchanges of feedback between student peers.

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