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Evaluation of a Hybrid Learning Block Model for Engineering Design Interview Skill Building

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ABSTRACT

Design interviews with stakeholders are an important source of information that engineering designers can use to identify stakeholder needs and develop solutions that meet stakeholder requirements. However, engineering students often struggle to conduct effective design interviews. In this study, we investigated changes in engineering students' interview approaches after engaging with a novel pedagogical intervention called the Hybrid Learning Block model. We identified specific differences in student interviewing behaviors between pre-block and post-block interview tasks with proxy stakeholders. Compared to pre-block interview tasks, participants' post-block interviewing behaviors and approaches aligned more closely with recommended interviewing practices from literature. Participants more frequently exhibited interviewing behaviors related to deep exploration of stakeholder perspectives and demonstrated more advanced phrasing of questions. In addition, participants structured their post-block interview tasks in ways that more closely aligned with recommended practices, for instance by including more comprehensive interview introductions and employing a more diverse array of questioning techniques. Our findings also suggest improvements for future iterations of the hybrid learning blocks, such as including content more specifically tailored to common student interviewing mistakes. Students can benefit from scaffolded, evidence-based ways to improve their design interviewing skills, such as the hybrid learning blocks, that can ultimately support them in developing more appropriate design solutions.

Key words: Stakeholder interviews, asynchronous learning, engineering design

INTRODUCTION

Stakeholder interviews are an important source of information that can help engineering designers define design problems and gather feedback on solution concepts (Dieter and Schmidt 2013). However, studies have shown that engineering students may struggle to implement recommended design interview practices, such as asking open-ended questions (Bano et al. 2019) and adopting interviewee language (Mohedas, Daly, and Sienko 2014). These interview struggles may, in turn, limit engineering students' abilities to develop deep understandings of stakeholder needs and requirements to support design decision-making.

This study explored the use of a novel pedagogical intervention – the Hybrid Learning Block (HLB) model (Young et al. 2017; "Socially Engaged Design Academy" 2022) – to help engineering students develop design interviewing skills. The HLB model consists of online content review, feedback, in-person coaching, and reflection. Previous studies have investigated impacts of the HLB model on generating solution concepts (Lee, Daly, and Vadakumcherry 2018), conducting needs assessments (Loweth, Daly, Liu, et al. 2020a), and writing needs statements (Loweth, Daly, Liu, et al. 2020b). The goal of this study was to investigate the HLB model as a tool to support students in preparing and conducting interviews with design stakeholders.

BACKGROUND

Previous Approaches to Design Interview Pedagogy

Prior literature has discussed several approaches to teaching design interviewing within engineering. For instance, Thompson & Beak (2007) suggested that collaborative learning – i.e., students working together in groups to complete a certain task – can be a useful pedagogical approach to support students in developing effective interview questions. Zowghi & Paryani (2003) suggested that roleplay activities, where engineering students alternate between interviewer and interviewee roles, can support students in developing interviewing skills. Additionally, Ferrari et al. (2020) suggested that a combination of roleplay, peer review, and self-assessment can help engineering students exhibit fewer interviewing mistakes.

Prior work has also described several ways to evaluate the efficacy of pedagogical interventions related to design interviewing. Zowghi & Paryani (2003), who implemented their intervention within the context of a requirements engineering course, gathered regular feedback from students and teaching staff and provided a detailed account of lessons learned from their course experience. Other studies have evaluated pedagogical interventions by comparing the interviewing knowledge and skills of students pre- and post-intervention. For example, Bano et al. (2019) used a pre-post study design to evaluate the impact

of a pedagogical approach consisting of collaborative roleplaying and corrective feedback. However, their study detected few changes in the quality of student interviews – which the authors defined as the frequency with which students exhibited common interviewing mistakes – due to their intervention. Building upon this work, Ferrari et al. (2020) adopted a pre-post study design and demonstrated an improvement in student interviewing approaches. Ferrari et al. (2020) also based their findings on the quantity of student interviewing mistakes. Research on improving design interviewing skills has not often focused on other potential measures, such as the degree to which students employ effective interviewing practices. Further, a collection of multiple ways to measure changes in student interviewing approaches would be beneficial to understanding student progress and the impact of different educational approaches on supporting design interviewing skill development.

The Hybrid Learning Block Model

The Hybrid Learning Block model is a pedagogical approach consisting of online content and knowledge checks, personalized feedback, in-person coaching on skills application within open-ended situations, and self-reflections on learning progress. The HLB model is built on several recommended practices in learning and teaching, such as active engagement with material (Prince 2004), personalized and timely feedback (Angelo and Cross 1993), clear articulation of learning goals (Pintrich and Zusho 2003; Wigfield and Eccles 2000), and skill application in realistic problem-solving contexts (Lima, Oakes, and Gruender 2006; Howe and Goldberg 2019). Using the HLB model, design training is offered to engineering students at whatever point best serves their needs, and engineering instructors can embed content related to design skill development within their curricula without needing expert knowledge on the particular topic.

In the HLB model, students are guided through five components, represented in Figure 1. The "Prior Knowledge Review" first asks students to reflect on their preconceptions and their motivations for learning about the design topic. The "Core Content" then outlines the learning goals for

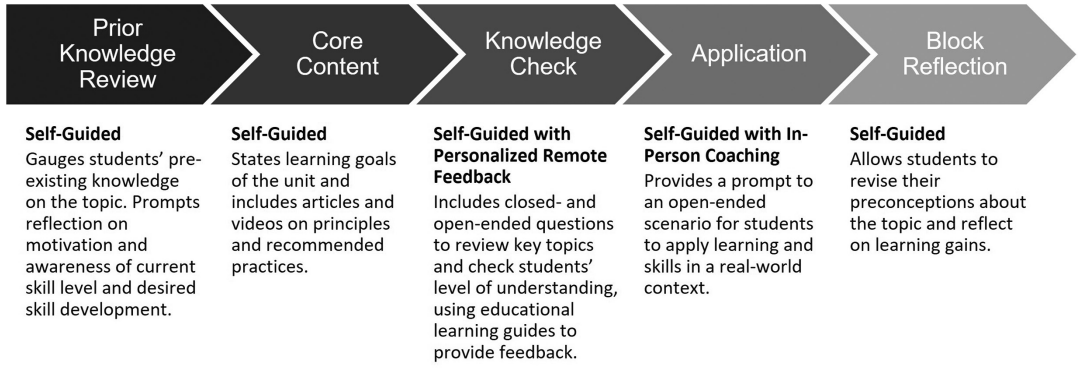


Figure 1. The Hybrid Learning Block Model.

the block, supplies readings and videos to guide students through key aspects of the topic, and introduces real-life examples. "Knowledge Checks" use a combination of closed-ended and open-ended questions to evaluate students' understanding of key ideas. Remote feedback is given through the online platform by trained graders. The "Application" requires students to apply the concepts introduced in the block to a real-life design scenario, and students are given personalized feedback by a coach during an in-person or virtual meeting that they use to revise their approaches. Lastly, the "Reflection" asks students to identify how their pre-existing ideas about the topic have been challenged or expanded by the block material and to consider future applications of the material to their own work. The hybrid learning blocks are hosted online through the University of Michigan's Center for Socially Engaged Design (https://umich.catalog.instructure.com/browse/csed/). Each hybrid learning block takes between four and six hours to complete.

Preliminary work by Young et al. (2017) demonstrated that the hybrid learning blocks can support students in deepening their understanding of recommended interviewing practices. This preliminary study served as a foundation for our present study. Our study also builds upon additional work that has previously evaluated the HLB model as a tool for developing other types of design skills. For example, Lee et al. (2018) explored how the HLB model impacted engineering student approaches to concept generation, development, and selection and found that the hybrid learning blocks helped students generate a greater number of ideas and systematically explore their solution spaces. Furthermore, Loweth et al. (2020a) investigated how the HLB model assisted a co-curricular design team in developing skills related to assessing community needs. They found that the blocks prompted students to identify how their backgrounds influenced their perceptions of community needs and to recognize the value of interacting with a wide range of stakeholders when assessing needs.

METHODS

Research Question

Our study was guided by the following research question: In what ways do engineering student interviewing approaches change after completing hybrid learning blocks related to planning and conducting design interviews?

Participants

Data were collected from seven engineering students enrolled at a large Midwestern university. As qualitative research facilitates deep exploration of phenomena (Leydens, Moskal, and

Pavelich 2004; Borrego, Douglas, and Amelink 2009; Creswell and Plano Clark 2018), the sample size of our study enabled us to gather deep information about participants' interviewing practices so that we could characterize impacts of the hybrid learning blocks on these practices. Participants were recruited through emails offering an opportunity to participate in testing of the HLB model. Emails were sent to undergraduate and graduate student listservs in engineering departments, and volunteers were deemed eligible to participate if they indicated little to no previous experience with stakeholder interviewing and were currently enrolled at the university. Participants received $100 for completing all study components. Participant demographics are reported in Table 1.

Table 1. Demographic information of study participants.

Participant	Race/Ethnicity	Gender	Year	Major
A	Asian	Woman	Sophomore	Industrial & Operations Engineering
B	Asian, White	Woman	Senior	Mechanical Engineering
C	Asian	Man	Freshman	Mechanical Engineering
D	White	Woman	Sophomore	Biomedical Engineering
E	White	Woman	Master's	Material Science & Engineering
F	White	Man	Master's	Civil & Environmental Engineering
G	American Indian, White	Woman	Sophomore	Biomedical Engineering

Engineering Design Interviews Hybrid Learning Blocks

This study leveraged two hybrid learning blocks: 'Crafting Design Interview Protocols' and 'Conducting Design Interviews.' The 'Crafting Design Interview Protocols' block introduced several recommended practices from the literature for developing interview protocols. For instance, interview protocols should organize open-ended questions around specific topics (Jacob and Furgerson 2012; Patton 2015; Spradley 1979). Protocols should also include a scripted introduction that outlines the interview purpose, notifies interviewees of recording procedures and asks for interviewee consent (Jacob and Furgerson 2012; Patton 2015), as well as a scripted conclusion that invites interviewees to discuss remaining questions and describes next steps in the data collection process (Jacob and Furgerson 2012; Patton 2015). The hybrid learning block also provided examples of effective open-ended questions drawn from Spradley (1979) and Patton (2015) and discussed suggestions from Spradley (1979), Patton (2015), and Allison (2013) for building rapport with interviewees. The application task for the block asked students to craft a design interview protocol based on a provided design problem scenario. Students received feedback on their protocols during their coaching sessions.

The 'Conducting Design Interviews' block discussed recommended literature practices related to the logistics of design interviews, such as choosing an interview location and seating arrangement that limits distractions but is also comfortable for the interviewee (Jacob and Furgerson 2012; Given 2016). The 'Conducting Design Interviews' block also emphasized other literature recommendations such as maintaining neutrality during interviews to avoid biasing interviewee responses (de Clerck et al. 2011) and actively listening to interviewee responses in order to probe these responses for greater depth (Roulston 2008). The application task for this block had students conduct a mock interview based on a design problem scenario. A summary of the topics included in the 'Crafting Design Interview Protocols' and 'Conducting Design Interviews' hybrid learning blocks is shown in Figure 2.

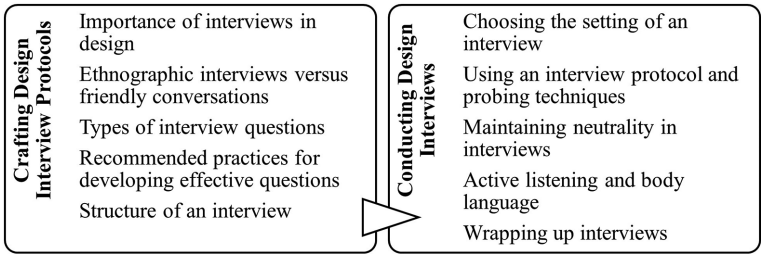
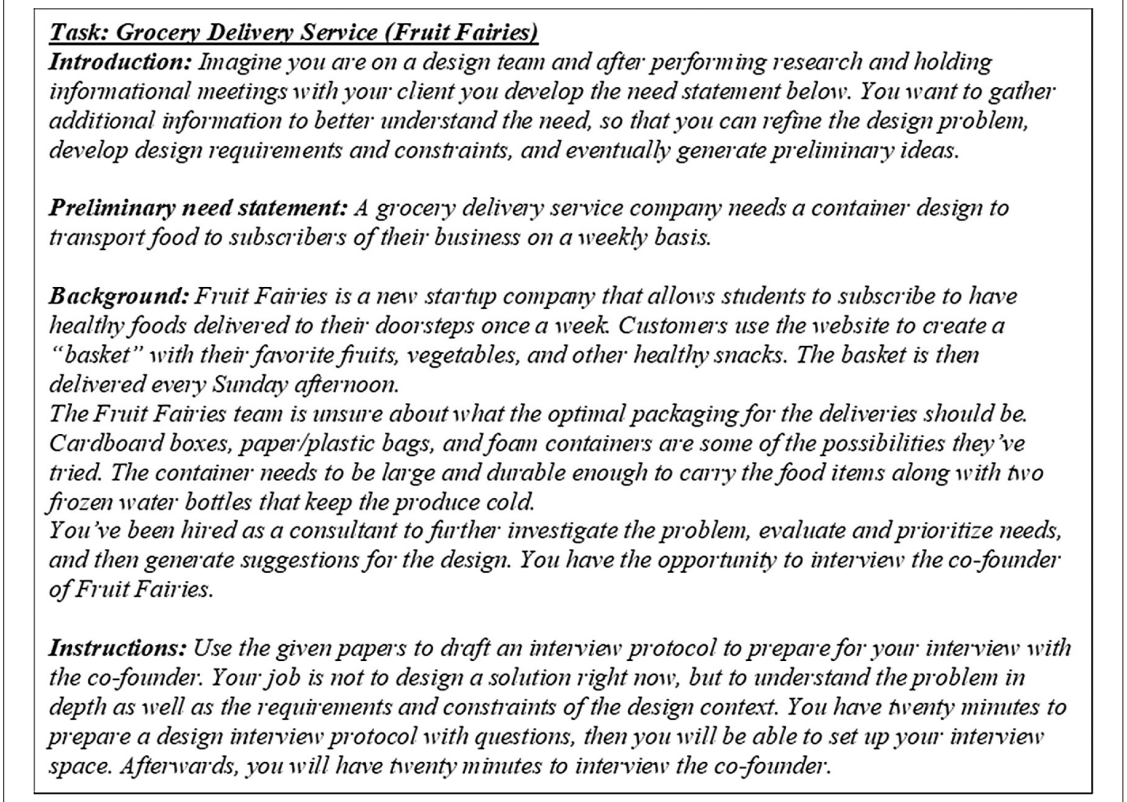


Figure 2. Key topics included in the 'Crafting Design Interview Protocols' and 'Conducting Design Interviews' hybrid learning blocks.

Data Collection

Each participant completed two mock interview tasks, one prior to completing the 'Crafting Design Interview Protocols' and 'Conducting Design Interviews' hybrid learning blocks (the "pre-block" interview task) and another after (the "post-block" interview task). During each interview task, participants were given one of four prompts that contained a hypothetical design problem description with ambiguous preliminary constraints. These four prompts were design problems related to: 1) a portable hygiene device, 2) food delivery containers, 3) martial arts equipment, and 4) home organization systems. An example of a prompt – the food delivery container problem – is shown in Figure 3. The other prompts were provided in a similar format.

Prior to engaging in the pre-block interview task, participants were interviewed by a member of the research team about their prior experiences conducting design interviews. Participants were then given 20 minutes to develop an interview protocol based on one of the four design prompts (selected by the researcher). After completing their interview protocols, participants were provided 20 minutes in a private room to interview a person (different for each design task) who served as a proxy stakeholder, i.e., an informed person representing a stakeholder for the design problem.



Task: Grocery Delivery Service (Fruit Fairies)

Introduction: *Imagine you are on a design team and after performing research and holding informational meetings with your client you develop the need statement below. You want to gather additional information to better understand the need, so that you can refine the design problem, develop design requirements and constraints, and eventually generate preliminary ideas.*

Preliminary need statement: *A grocery delivery service company needs a container design to transport food to subscribers of their business on a weekly basis.*

Background: *Fruit Fairies is a new startup company that allows students to subscribe to have healthy foods delivered to their doorsteps once a week. Customers use the website to create a "basket" with their favorite fruits, vegetables, and other healthy snacks. The basket is then delivered every Sunday afternoon.*
The Fruit Fairies team is unsure about what the optimal packaging for the deliveries should be. Cardboard boxes, paper/plastic bags, and foam containers are some of the possibilities they've tried. The container needs to be large and durable enough to carry the food items along with two frozen water bottles that keep the produce cold.
You've been hired as a consultant to further investigate the problem, evaluate and prioritize needs, and then generate suggestions for the design. You have the opportunity to interview the co-founder of Fruit Fairies.

Instructions: *Use the given papers to draft an interview protocol to prepare for your interview with the co-founder. Your job is not to design a solution right now, but to understand the problem in depth as well as the requirements and constraints of the design context. You have twenty minutes to prepare a design interview protocol with questions, then you will be able to set up your interview space. Afterwards, you will have twenty minutes to interview the co-founder.*

Figure 3. A task prompt provided to student participants during the interview task prep period.

On average, participants' pre-block interviews lasted 15.4 minutes (i.e., participants typically ended their interviews early). Each participant performed their interview task individually and there was no collaboration between participants. The proxy stakeholders were volunteers with stakeholder interview experience who were trained how to simulate typical stakeholder behavior (such as responding appropriately and with sufficient depth to questions asked) by staff at the University of Michigan's Center for Socially Engaged Design.

Participants were given two weeks to complete the 'Crafting Design Interview Protocols' and 'Conducting Design Interviews' hybrid learning blocks on their own timing. Following block completion, participants were asked to complete a post-block interview task. The post-block interview task followed the same interview protocol preparation and stakeholder interview procedures as the pre-block interview tasks, with the exception that participants were provided with a new design prompt. On average, participants' post-block interviews lasted 14.5 minutes. After completing their

post-block interview task, participants were again interviewed by a member of the research team, this time about their experiences with the hybrid learning blocks and the pre- and post-block interview tasks. The pre- and post-block interview tasks and researcher-led interviews of each participant were audio and video recorded (totaling approximately 1.5 hours of audio per participant), then later transcribed for further analysis by team members. The full sequence and description for each component of the study is demonstrated in Figure 4.

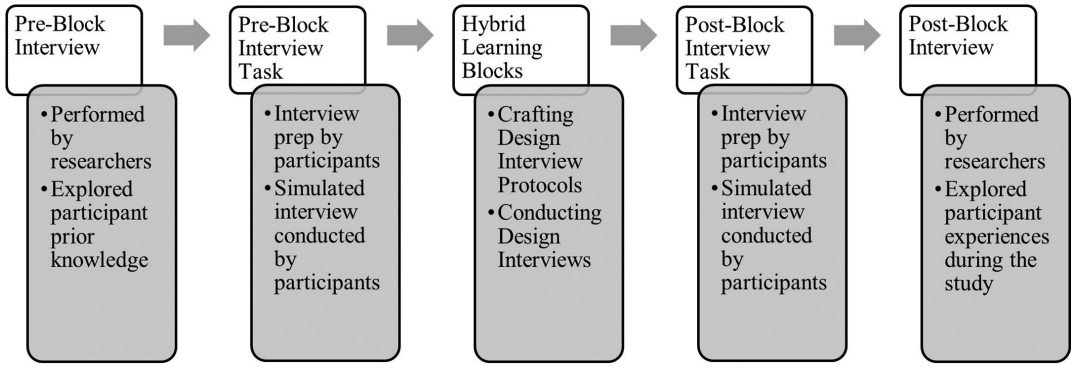


Figure 4. Sequence of events for each participant within the study.

Data Analysis

Transcripts of participant pre-block and post-block interview tasks were first reviewed several times by two members of the research team. The two researchers then deductively coded the interview transcripts using a list of interviewing behaviors adapted from Loweth, Daly, Hortop et al. (2020). A brief example of this coding approach is shown in Table 2.

In the original list from Loweth, Daly, Hortop et al. (2020), interviewing behaviors were grouped into behaviors that were more similar to recommended practices, such as *encourage*

Table 2. Example of interviewing behaviors identified in participant interview tasks.

Example	Interviewing behavior	Definition of behavior	Categorization
How would you describe your relationship with your housemates? (Participant 10, post-block)	Encourage Deep Thinking	Students ask questions that encourage the stakeholder to move beyond superficial responses and provide in depth knowledge on subject	*Exploratory,* More similar to recommended practices
"How did you prepare for this trip? Did you go online? Did you talk to other people about their experiences? (Participant 4, post-block)	Elicit Shallow Responses	Students ask questions that implicitly constrain stakeholder responses	*Exploratory,* Less similar to recommended practices

deep thinking, and less similar, such as *elicit shallow responses*. Behaviors were also classified as either *structural*, *exploratory*, or *collaborative* based upon the type of information elicited and the contexts in which students employed each behavior. *Structural* interviewing behaviors related to interview organization and basic clarification. *Exploratory* interviewing behaviors explored stakeholder perspectives and experiences in depth. C*ollaborative* interviewing behaviors bridged differences in understanding between students and stakeholders resulting from differences in background or domain knowledge. The full list of interviewing behaviors can be found in Table A1 (Appendix).

The two researchers each coded the 14 interview task transcripts in parallel using the list of interviewing behaviors. During this initial round of coding, the two researchers discussed challenges that they encountered while coding the transcripts and compared their respective coding approaches to identify initial discrepancies. As coding continued, the two researchers iteratively discussed and resolved discrepancies in their interpretations of participants' interviewing behaviors. By the end of this initial round of coding, the two researchers had reached preliminary negotiated agreement as to the frequency and distribution of each interviewing behavior across the 14 interview task transcripts. "Frequency" in this case referred to the number of independent instances of each behavior within a given transcript. "Distribution" referred to the location(s) of each behavior within a given transcript and the duration of these behaviors (i.e., some instances of a given behavior had longer "durations" if they solicited extensive responses from interviewees prior to participants introducing a new topic of discussion). The two researchers then reviewed transcripts one more time to ensure 1) that there were no further disagreements or confusions related to the frequency and distribution of interviewing behaviors within and across transcripts and 2) that all segments of participants' transcripts had been assigned to a relevant interviewing behavior.

To determine the reliability of our coding approach, the two researchers waited several weeks and then chose four interview transcripts to re-code. These four transcripts were chosen because they included a diverse sample of interviewing behaviors. The goal of this re-coding was to determine the inter-rater reliability of our coding approach at the line-by-line level. As such, while the two researchers were generally aware of which interviewing behaviors were contained in the sample of four transcripts, they did not review the exact frequency or distribution of these behaviors prior to attempting to re-code. Upon completing their re-coding of the four transcripts, the inter-rater reliability between the two researchers was calculated to be 76.6%, indicating high agreement (Cohen 1960; Hallgren 2012).

Once coding was completed, we performed several analyses to identify and describe differences between participant pre-block and post-block interview tasks. Our goal in performing multiple analyses was to explore comprehensively the various ways that the interviewing learning blocks

may have affected participants' interviewing approaches. Our analysis included 1) comparing the frequency of different types of interviewing behaviors exhibited by participants, 2) assessing how participants exhibited these behaviors within their interviews and 3) developing timelines to compare the structure and flow of participants' interviews.

Our coding approach enabled us to identify, with a high degree of reliability, how many times participants exhibited each interviewing behavior during each of their interview tasks. Thus, we sought to determine whether there was a difference in the mean frequency (i.e., mean number of instances) of "*exploratory* behaviors that were more similar to recommended practices" (*encourage deep thinking, flexibly & opportunistically probe responses, verify the conclusions drawn from meetings, delve into stakeholder experiences*) in participants' post-block interview tasks compared to pre-block interview tasks. The content of the hybrid learning blocks primarily described recommended practices corresponding to these behaviors. Participants also had equal amounts of time (20 minutes) to complete their pre-block and post-block interview tasks. Thus, an increase in the mean frequency of "*exploratory* behaviors that were more similar to recommended practices" between pre-block and post-block interview tasks would suggest that the learning blocks supported participants in employing *exploratory* interviewing techniques more consistently during interviews. We also sought to determine if there was a corresponding decrease in the mean frequency of "*exploratory* behaviors that were less similar to recommended practices" (*elicit shallow responses, rigidly adhere to structure, lead the stakeholder to conclusion, conflate student and stakeholder experiences*) between pre-block and post-block interviewing tasks as a result of participants completing the learning blocks.

We performed two paired permutation tests on our data to investigate differences in the mean frequency of *exploratory* interviewing behaviors between pre-block and post-block interview tasks. As described by Collingridge (2013), permutation tests offer several advantages that make them appropriate for analyzing mean differences in quantized qualitative data. For instance, permutation tests, unlike parametric tests, do not rely on assumptions of normality. Permutation tests between groups are also appropriate for small sample sizes, provided that the number of matched pairs is greater than n = 5. We performed paired permutation tests on our data using the wPerm (https://rdrr.io/cran/wPerm/) library in R, with a random set seed value of 123. Our first permutation test tested whether, across participants, the mean frequency (i.e., mean number of instances) of "*exploratory* behaviors that were more similar to recommended practices" in post-block interviews was *greater* than the mean frequency of such behaviors in pre-block interviews. Our second permutation test tested whether the mean frequency of "*exploratory* behaviors that were less similar to recommended practices" in post-block interviews was *less* than the mean frequency of such behaviors in pre-block interviews.

Our second method of analysis assessed how participants exhibited specific behaviors within their interviews. Specifically, we compared the features (e.g., specificity, comprehensiveness of detail, etc.) of participants' pre-block and post-block interviewing behaviors to determine whether the hybrid learning blocks supported students in implementing certain interviewing behaviors in ways that better aligned with recommended practices. Participants, during pre-block interviews, exhibited some instances of *exploratory* interviewing behaviors that aligned with recommended practices. Participants also consistently employed *structural* interviewing behaviors during both pre-block and post-block interviews. The goal of this analysis method was thus to explore how the hybrid learning blocks built upon and supported the expansion of participants' prior knowledge. A secondary goal was to highlight changes in participants interviewing techniques that were not revealed through our analysis of counts.

For each participant, the two coders identified excerpts from pre-block and post-block interview tasks that they had coded as representing the same type of interviewing behavior. The two coders then identified and described qualitative differences in the language or approaches employed by participants as part of these interviewing behaviors in post-block interview tasks compared to pre-block interview tasks. For example, a participant might have *delved into stakeholder experiences* in both pre-block and post-block interview tasks but demonstrated more sophisticated approaches to phrasing questions in their post-block interview task.

Our third method of analysis explored the distribution (i.e., the timing and duration) of participants' interviewing behaviors within each transcript. To perform this analysis, we constructed and compared timelines (time resolution = 15 seconds) of each participant's interview tasks. These timelines modeled the sequencing of participants' interviewing behaviors within each transcript and the time duration of proxy stakeholder responses to participants' questions. The goal of this analysis method was to determine whether the hybrid learning blocks affected the structure and flow of participants' interviewing approaches. Timelines have been used previously to communicate and analyze design processes and have been cited as memorable and useful representations of abstract data models (Atman 2019). The main difference between the timelines that we constructed for this study and previous uses of design timelines is that our timelines described a specific design activity rather than a full design process. As such, our timelines show how participants transitioned between different interviewing behaviors rather than between different design stages as in Atman (2019). An example of one of the constructed interview timelines is provided in our findings (Figure 5).

We did not analyze participant responses from researcher interviews as part of this study. Rather, we used these supplementary data to verify our findings from our analyses of participants' interview tasks.

FINDINGS

Frequency of *Exploratory* Behaviors (Analysis Method #1)

On average, participants exhibited 4.1 *more* instances of "*exploratory* behaviors that were more similar to recommended practices" in post-block interview tasks compared to pre-block interview tasks (p = 0.015). Participants also exhibited, on average, 4.0 *fewer* instances of "*exploratory* behaviors that were less similar to recommended practices" in post-block interview tasks compared to pre-block interview tasks (p = 0.038). The frequency of *exploratory* behaviors for each participant is provided in Table 3.

Table 3. Instances of* exploratory *interviewing behaviors exhibited by participants in pre-block and post-block interview tasks.

	Instances of "*exploratory* behaviors that were more similar to recommended practices"		Instances of "*exploratory* behaviors that were less similar to recommended practices"	
Participant	**Pre-block interview**	**Post-block interview**	**Pre-block interview**	**Post-block interview**
A	4	3	2	4
B	3	10	13	10
C	8	15	11	0
D	5	11	6	1
E	9	14	7	6
F	6	8	11	2
G	10	13	2	1
Average across participants	**6.4**	**10.5**	**7.4**	**3.4**
Difference in averages		+4.1		–4.0
P-value (Permutation test)		0.015		0.038

Pre-Post Changes in How Participants Exhibited Interviewing Behaviors (Analysis Method #2)

There were two interviewing behaviors that most participants exhibited in both pre-block and post-block interview tasks: *guide meeting direction while inviting stakeholder input* and *delve into stakeholder experiences*. The ways that participants exhibited these two interviewing behaviors often changed between pre-block and post-block interview tasks to align more closely with recommended practices.

Five participants demonstrated improvements related to the behavior *guide meeting direction while inviting stakeholder input* (the other two participants did not exhibit this behavior in their

pre-block interview tasks). Pre-block instances of this behavior typically resembled the following example from Participant F:

> *Welcome to the interview… I have some questions for you about the martial arts dojo and some potential equipment storage problems that you guys are having. How long have you been involved with [the dojo]?*

Prior to completing the hybrid learning blocks, Participant F did greet the interviewee and provided a brief explanation of the interview purpose before proceeding to their main interview topics. However, Participant F's introduction lacked essential components such as confirmation of interviewee consent and clarification that the interviewee may decline to answer questions if they so choose. By comparison, the next excerpt, again from Participant F, represents a typical example of the *guide meeting direction while inviting stakeholder input* behavior in post-block interview tasks:

> *All right, so before we get going here, I would like to first go over a few things with you and make sure we're on the same page… I'm here because I'm interested in learning more about a problem you've been having with cleaning in your house. And I would like to take the time today to talk to you about some questions I have as far as that goes and try and learn what I can … but before we begin, I want to make sure that it's okay if I interview you today? … I'd also like to record the interview, if that's okay with you, so I can review it later… Okay, thank you very much. Then the last thing before we get started, I just want to point out that there's really no right or wrong answers or preferred answers in this interview, so I'd encourage you to answer openly and honestly when you can. If I ask any questions that… you're not comfortable answering, feel free to say, "I'm sorry, I'd prefer not to answer that question." All right?… Do you have any questions for me before we begin?*

After completing the hybrid learning blocks, Participant F's introduction contained several additional components, including confirmation of interviewee consent to record the interview, encouragement to answer questions honestly, and a clarification that the interviewee did not have to answer all questions. Participant F's post-block introduction was thus more in line with recommended practices and demonstrated a level of improvement that was observed across other participants in our study as well.

Five participants demonstrated improvements related to the behavior *delve into stakeholder experiences* between pre-block and post-block interview tasks (one participant did not exhibit this

behavior in their pre-block interview task, another was already exhibiting this behavior at an advanced level in their pre-block interview task). For instance, in pre-block interview tasks, participant approaches to exploring their interviewee's experiences typically resembled the following example from Participant D:

> *I wanted to start by asking what ... Just tell me about the problem, in your own words. I have some information here, but I just wanted to hear about it from you.*

In their pre-block interview task, Participant D attempted to dive into their subject matter after introductions by asking the interviewee to describe their problem. This line of questioning is open-ended and solicits the interviewee's perspective; however, the lack of specificity in the question as phrased may have led the interviewee to misunderstand what aspects of their experiences were most relevant to discuss with the interviewer. By comparison, the next excerpt, again from Participant D, represents an example of the *delve into stakeholder experiences* behavior in post-block interview tasks:

> *All right, can you walk me through the process, step by step, of how you would order food from [Grocery Service], from the time that you want to start subscribing to the service to the time that you actually get food at your doorstep?"*

As before, this initial kick-off question is open-ended and solicits the interviewee's perspective. However, after completing the hybrid learning blocks, Participant D also grounded their initial kick-off question within a specific, concrete experience of the interviewee. By doing so, Participant D clearly signaled that they wanted to learn more about the food delivery process that a user would go through with the service, thus helping the interviewee to provide relevant information. This level of improvement was typical of participants who demonstrated changes related to the *delve into stakeholder experiences* behavior.

Changes in Structure and Flow of Interview Tasks (Analysis Method #3)

By comparing timelines of the pre-block and post-block interview tasks, we found evidence of changes in the structure and flow of participants' interview tasks. An example showing the interview tasks conducted by Participant B is shown in Figure 5; this example demonstrates many of the changes we observed between pre-block and post-block interview tasks.

In their pre-block interview, Participant B relied substantially (50% of their interview time) on the *elicit shallow responses* behavior to solicit information from their interviewee. They exhibited

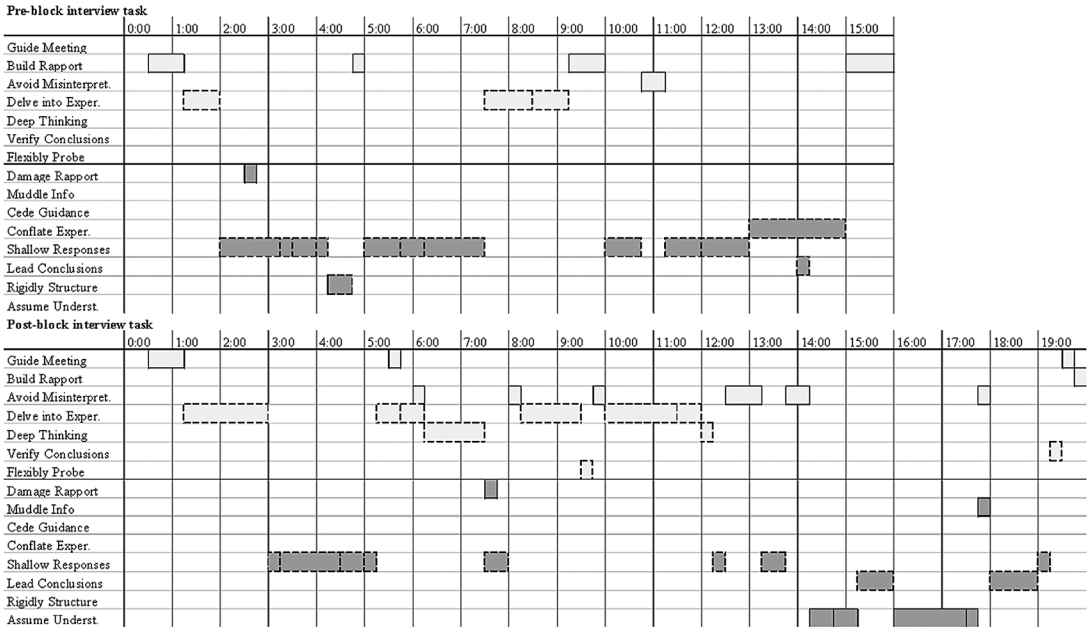


Figure 5. Timelines (time resolution = 15 seconds) of pre-block (top) and post-block (bottom) interview tasks conducted by Participant B. Interviewing behaviors that were more similar to recommended practices are colored light grey, while behaviors that were less similar to recommended practices are colored dark grey. Repeated instances of the same behavior are separated by vertical borders. **Exploratory** ***behaviors are represented with dotted black outlines.***

relatively few instances of *exploratory* behaviors that were similar to recommended practices and did not seem to consistently utilize *structural* behaviors like *guide meeting direction while inviting stakeholder input*, *build rapport with the stakeholder*, or *avoid misinterpretations* to structure the interview.

By comparison, Participant B demonstrated a more advanced interview structure and more sophisticated interviewing approaches in their post-block interview task. Participant B began by introducing the purpose of the interview (the first 45 seconds of *guide meeting direction while inviting stakeholder input*) before variously employing the *delve into stakeholder experiences* and *encourage deep thinking* behaviors to solicit in-depth information from the interviewee. Participant B also regularly employed the *avoid misinterpretations* behavior to clarify interviewee responses before transitioning to a new topic. While these behaviors reflect a more advanced interview approach, there were still several instances (although fewer than in their pre-block interview) where Participant B employed behaviors such as *elicit shallow responses* and *lead the stakeholder to*

conclusion that were less similar to recommended practices. Participant B's timelines thus highlight a specific case in our data where a participant increased their use of *exploratory* interviewing behaviors that were more consistent with recommended practices, yet still exhibited a relatively high frequency of *exploratory* behaviors that were inconsistent with recommended practices in their post-block interview.

The changes in interview structure and flow highlighted by Participant B's timelines occurred across our data. Table 4 summarizes the frequency of these changes in participants' post-block interview tasks compared to their pre-block interview tasks.

Table 4. Changes in interview flow and structure exhibited by participants in post-block interview tasks

Type of Change in Post-block Interview Tasks	Number of Participants (Out of 7) to Exhibit Change
More comprehensive interview introduction	7
Use of multiple *exploratory* interviewing behaviors	6
Reduced use of *elicit shallow responses*	4
Consistent use of *structural* interviewing behaviors throughout interview	4

DISCUSSION

Our analysis revealed several differences between the pre-block and post-block engineering student design interview tasks, including: a higher frequency (i.e., number of instances per interview) of "*exploratory* behaviors that were more similar to recommended practices" in post-block interview tasks, a lower frequency of "*exploratory* behaviors that were less similar to recommended practices" in post-block interview tasks, closer alignment between student interviewing behaviors and recommended practices in post-block interview tasks, and more advanced interview structures featuring a wider variety of interviewing behaviors in post-block interview tasks. Since the main difference between the two interview tasks for each participant was the completion of the 'Crafting Design Interview Protocols' and 'Conducting Design Interviews' hybrid learning blocks, our findings suggest that these two blocks effectively supported engineering students in conducting design interviews that aligned more closely with recommended practices. The *exploratory* interviewing methods that increased most in frequency between the pre- and post-block interview tasks were the *delve into stakeholder experiences* and *encourage deep thinking* behaviors. Bano et al. (2019) cited both practices as behaviors that novice designers tend to struggle with during interviews; the HLB model served as an appropriate intervention to address those specific student challenges.

Our findings demonstrate that there are many ways that student interviewing skills may evolve in response to design interview pedagogy. While previous studies such as Bano et al. (2019) and Ferrari et al. (2020) mainly focused on changes in the frequency of students' interviewing mistakes, our study showed that the frequency of student interviewing behaviors that align with recommended practices, the language and approaches that students employ as part of these behaviors, and the structure of student interviews may change as well. By triangulating across these three different growth metrics, we were able to corroborate our findings related to each individual metric while also describing the impacts of our pedagogical intervention in greater depth than previous studies.

The results of our paired permutation test also indicated that, on average, the frequency of *exploratory* behaviors that were less similar to recommended practices decreased between interview tasks. However, as highlighted in the example of Participant B's interview timelines, this decrease varied substantially across participants. For instance, Participants B and E, in post-block interview tasks, both exhibited relatively high frequencies of *exploratory* behaviors that were more similar to recommended practices and also high frequencies of *exploratory* behaviors that were less similar to recommended practices. One possible explanation is that this finding reflects the novice skill level of our participants. Frameworks of novice designer skill building (e.g., Mohedas, Daly, and Sienko 2016; Crismond and Adams 2012) emphasize that there are multiple learning progressions that students may go through as they develop design skills. Novice designers at an intermediate stage in their skill development may exhibit both novice and more expert behaviors simultaneously, which may be why other studies of design interviewing pedagogy such as Bano et al. (2019) have similarly observed that pedagogical interventions may not consistently reduce the occurrence of interview mistakes.

Another possible explanation is that the avoidance of design interviewing mistakes may represent a separate learning outcome from the improvement of interviewing techniques. For instance, the "Core Content" materials of the hybrid learning blocks described how students might exhibit recommended practices in their interviews but typically did not highlight interviewing behaviors that students should avoid exhibiting. Our assumption in preparing these materials was that elucidation of recommended interviewing practices would also help engineering students avoid less desirable interviewing behaviors. While this assumption may hold for some students, our findings suggest that future iterations of our hybrid learning blocks should also explicitly target the reduction of less desirable interviewing behaviors, such as poorly worded or closed-ended questions, as an independent learning outcome. One way to achieve this learning outcome might be to supplement the current content related to recommended interviewing practices with additional examples of common mistakes made by novice interviewers. These additions will ideally help students consistently

exhibit fewer interviewing behaviors that are less similar to recommended practices as a result of completing the hybrid learning blocks.

Limitations

One limitation for our study was the simulated nature of the pre-block and post-block interview tasks. Since participants were engaged in simulated tasks, they may not have approached their interviews the same ways that they would have approached interviews in other contexts. The proxy stakeholders in this study also participated in interviews with multiple study participants. In some cases, interviewees seemed to provide information or comments that suggested that they may have been primed by conversations with other participants.

Another limitation is that we do not know which learning gains from completing the 'Crafting Design Interview Protocols' and 'Conducting Design Interviews' hybrid learning blocks remained salient for participants over time, given that participants might not have had consistent opportunities to practice interviewing stakeholders following the conclusion of our study.

Furthermore, our pre-post comparison evaluated the impacts of the hybrid learning blocks as a whole. As such, it is unclear which specific aspects of the blocks may have contributed most to the observed learning gains in our participants.

Lastly, six out of the seven participants identified their race as being either white or Asian. Moreover, the social context and lived realities of our participants were not investigated in depth within the context of this study. It is unclear whether or to what degree our findings might change with a different set of participants, or to what extent the backgrounds or social identities of students may influence their learning gains from completing the learning blocks.

Pedagogical Implications

Our findings indicate that the 'Crafting Design Interview Protocols' and 'Conducting Design Interviews' hybrid learning blocks supported engineering student approaches to conducting design interviews. At present, access to the blocks is limited and controlled through the University of Michigan. However, as these blocks are made publicly available, they could be a useful tool for instructors that are looking to teach students how to conduct effective design interviews but do not necessarily have the knowledge to do so. Instructors could embed the hybrid learning blocks within their curricula via an asynchronous platform, enabling students to engage in self-directed learning and proceed at their own pace. The Hybrid Learning Block model (Figure 1) can also serve as an example for other instructors who are developing their own design interview pedagogy.

Instructors may also use our findings to develop new tools for evaluating engineering students' design interviews. Our study suggests several methods, such as evaluating the language and

approaches that students employ as part of specific interviewing behaviors and analyzing the structure and flow of student interviews, that instructors may use to comprehensively gauge students' interviewing competencies. Students might also use these methods to self-assess their own interviews through structured reflections.

CONCLUSIONS

Our study identified specific ways that the Hybrid Learning Block model, specifically the 'Crafting Design Interview Protocols' and 'Conducting Design Interviews' blocks, supported engineering students in conducting effective design interviews. We found that, on average, the frequency of "*exploratory* behaviors that were more similar to recommended practices" increased between pre-block and post-block interview tasks. The frequency of "*exploratory* behaviors that were less similar to recommended practices" also decreased on average between interview tasks. However, this decrease varied substantially across participants, and future iterations of the hybrid learning blocks might target the reduction of less desirable interviewing behaviors as a standalone learning outcome. We also found that the language and approaches that participants exhibited as part of certain interviewing behaviors aligned more closely with recommended practices in post-block interview tasks. Lastly, we observed changes in the flow and structure of participants' interview tasks to be more in line with recommended practices. In conclusion, instructors can use the hybrid learning blocks (once publicly available) to supplement their engineering curricula and support student designers in conducting design interviews. Instructors may also use the metrics for evaluating student interviews discussed in this study to comprehensively gauge the interviewing abilities of their students and identify specific areas for improvement. Our findings thus highlight several ways that design instructors can support their students in conducting effective design interviews that enable them to develop deeper understandings of stakeholder needs and requirements in their design projects.

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APPENDIX

Table A1. List of student interviewing behaviors (adapted from Loweth, Daly, Hortop et al. (2020))

	More similar to recommended practices		Less similar to recommended practices	
	Behavior	**Definition**	**Behavior**	**Definition**
Structural Behaviors	**Build Rapport with the Stakeholder**	Students demonstrate an appreciation for the stakeholder's contributions and seek to help the individual feel comfortable during the meeting	**Damage Rapport**	Students express judgment of the stakeholder's contributions or otherwise cause the stakeholder to feel uncomfortable during the meeting
	Avoid Misinterpretations	Students repeat and clarify the stakeholder's responses to make sure that accurate information is being collected	**Muddle Information Received from the Stakeholder**	Students use imprecise language and/ or allow technical difficulties to decrease the clarity of the stakeholder's responses and thus insert ambiguities into collected information
	Guide Meeting Direction while Inviting Stakeholder Input	Students clarify the purpose of the meeting and consistently guide the meeting direction while also inviting the stakeholder to suggest topics of interest	**Cede Guidance of Meeting**	Students surrender to the stakeholder the position of guiding the meeting direction and/or exhibit uncertainty as to who should be guiding the meeting at a given moment
Exploratory Behaviors	**Encourage Deep Thinking**	Students ask questions that encourage the stakeholder to move beyond superficial responses and provide in depth knowledge on a given subject	**Elicit Shallow Responses**	Students ask questions that implicitly constrain stakeholder responses
	Flexibly & Opportunistically Probe Responses	Students employ spontaneous probes, as indicated by vocal cues indicating surprise or curiosity, to dive deeper into the stakeholder's experiences or knowledge	**Rigidly Adhere to Structure**	Students resist departing from the pre-determined topics of the meeting
	Verify the Conclusions Drawn from Meetings	Students check that their conclusions drawn from the meeting match with the stakeholder's own perceptions	**Lead the Stakeholder to Conclusion**	Students indicate a suggested or preferred answer when asking questions or soliciting feedback and thus influence the stakeholder's response
	Delve into Stakeholder Experiences	Students evoke specific ideas or experiences of the stakeholder to better understand how the individual thinks and feels about the design problem	**Conflate Student and Stakeholder Experiences**	Students suggest that the stakeholder's experiences likely resemble their own and do not explore the stakeholders's experiences in greater depth

Table A1. (Continued).

	More similar to recommended practices		Less similar to recommended practices	
	Behavior	**Definition**	**Behavior**	**Definition**
Collaborative Behaviors	**Use a Co-Creative Meeting Strategy**	Students establish space within the meeting for the stakeholder to make project decisions or give design feedback	**Use a Student-Centered Meeting Strategy**	Students control the goals of the meeting and project, making decisions and informing the stakeholder of those decisions rather than soliciting input on those decisions
	Develop Mutual Understanding with the Stakeholder	Students leverage language and/or design representations that help them to communicate across disciplinary barriers and develop mutual understanding about the design project	**Assume Stakeholder's Understanding**	Students embed assumptions about the stakeholder's understanding of the design project in their questions or language
	Introduce Relevant Information	Students provide relevant knowledge about the design project to build a repository of shared information between the design team and the stakeholder	**Introduce Unclear Information**	Students introduce information about the design project but do not clearly explain the meaning of the information and/or clarify that the information is likely inaccurate
	Explore Differences Between Perspectives	Students explore the nuances of the stakeholder's point of view by presenting the differing perspective of another stakeholder not present at the meeting	**Place Own Perspective Above Others'**	Students describe the perspectives of other stakeholders not present at the meeting but dismiss these other perspectives as irrelevant to the project