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Establishing qualitative inquiry to understand student experiences in online experimentation (Work in progress)

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Dr. May is an Assistant Professor in the Engineering Education Transformations Institute. He researches online and intercultural engineering education. His primary research focus lies on the development, introduction, practical use, and educational value of online laboratories (remote, virtual, and cross-reality) and online experimentation in engineering instruction. In his work, he focuses on developing broader educational strategies for the design and use of online

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Introduction

Prior to the global pandemic that led to unprecedented, widespread changes in instructional strategies, students' participation in online laboratory learning was often their prerogative, with seeming advantages and disadvantages. Though past research about online learning, in general, may shed light on instruction with online labs—e.g., [1], [2]—the experiential emphasis of *laboratory* learning presents unique challenges in an online environment that must be addressed. Online labs have gained interest in education over the last decades. Starting with rather simple, remotely accessible equipment [3] we can see new examples such as augmented and virtual reality technology making progress for teaching and learning [4]. Efforts from diverse scientific fields, including computer science, education, and STEM-disciplines research have contributed to efforts for online lab experiences.

Scanning across implementations of online laboratories, there are three approaches: remote laboratories, augmented laboratories, and virtual laboratories [5] – [7]. The term remote laboratory describes an experimental setup that makes use of physically existing equipment, but the experimental procedure itself can be conducted via the internet from virtually everywhere and at any time. The use of real equipment and resulting impacts on data acquisition (e.g., the existence of electrical noise in circuits) represent the biggest difference between the use of remote labs and the use of simulations. Augmented laboratories include experimental setups, which are enhanced with augmented reality during experimentation, e.g., to display real-time data at experimental equipment's point of origin. Virtual laboratories refer to virtual environments and make use of simulations instead of real equipment for the experimental procedure. These virtual laboratories are typically desktop-based solutions, but there are also examples of full immersive labs in which students can even collaborate in virtual worlds [8]. All of the above-mentioned approaches include opportunities, as well as challenges, in terms of flexibility, capacity, range, audience, and teaching and learning methods. in terms of flexibility, capacity, range, audience, and teaching and learning methods.

The scholarly debate about the advantages and disadvantages of online laboratories is highly vivid, with multiple scientific reviews of the advantages, disadvantages, and challenges of instruction with online laboratories [4], [9], [10]. However, it is fair to say that online labs generally add a layer of flexibility and accessibility to course delivery, as online labs avoid constraints typical for lab-based instruction like the number work stations in a lab or simply course time. In addition, research shows that well-designed online labs "can be as effective as a traditional face-to-face laboratory experience when measuring either content knowledge or student opinions as the metric for equivalence" [11, p. 162]. Nevertheless, it is also emerging that the choice for an instructional format depends heavily on respective circumstances defined by the institution, the teacher, and the learner—given these seeming advantages or disadvantages and students' individual needs they might have chosen to enroll in a course or program of study with partial or full online interaction.

Yet, College of Engineering programs at the University of Georgia responded to the pandemic by an instructional pause and a *widespread* shift to online instruction for the remainder of the Spring 2020 semester and Summer 2020. Instruction through the 2020 – 2021 academic year was offered in a mixture of formats including hybrid instruction. We leveraged prior work related to online experimentation to develop online laboratory experiences for the "Fundamentals of Circuit Analysis" course through two platforms, Emona and LabsLand VISIR, which we have described elsewhere [12, 13]. In short, these remote laboratory platforms provide a digital connection to real-world circuitry and the interfaces are designed to mimic real-world circuit design and instrumentation, such as an oscilloscope and multimeter.

Even though research on the learning side of online laboratories has been on the rise for the last 20 years, there is still much room for investigation. In particular, research with rigorous study designs is needed to go beyond student satisfaction surveys and innovation case studies [6]. The mandated, widespread participation in online experimentation during the pandemic showed the opportunity to study broad perspectives, even from those that might not otherwise have adopted the use of online labs—"laggards" or "late adopters" [14]. And we have worked to satisfy the need for rigorous study of these instructional settings.

Our work focuses on two aspects of a theoretical framework for learner engagement—cognitive and emotional engagement [15]. Cognitive engagement pertains to students' thoughtfulness and effort to master difficult skills and concepts. Emotional engagement pertains to their reactions to the learning environment, willingness to do the work, and perceptions of value from the content. In line with ways that engagement these forms of engagement are demonstrated, i.e., that they can be operationalized as self-regulation and motivation [16] – [20], we have organized a stream of research related around the research question, "How does online experimentation impact students' learning experiences in terms of engagement, investigated through self-regulation and motivation?" We see these forms of engagement in line with the affordances or challenges of online learning described earlier: though enrollment in this format was mandated, students' engagement may be manifest by whether and how students see value in the material and the additional flexibility of online experimentation may manifest in ways that the students self-regulate to navigate the content. Though necessary adaptations to instruction have been reduced since the start of the pandemic, we have conducted ongoing research to gather student perspectives of online laboratory learning.

This work-in-progress paper describes the development of our qualitative methodologies to address this research question. Three main activities are described, including 1) the systematic development of a data gathering protocol using the interview protocol refinement framework (IPR), 2) our approach to paired thematic analysis to develop a coding scheme, and 3) the integration of a qualitative, machine-learning-based strategy to corroborate the coding scheme and uncover further insight from discussion of online experimentation. This work will inform a model for student-centered online experimentation with explicit guidelines for student support. The qualitative methods described herein demonstrate our careful attention to understand students' experiences and build a foundation for forthcoming findings.

Interview Protocol Development

The choice to conduct interviews depends on the purpose of the research and the research questions being asked; we are prudent to follow this avenue of inquiry for understanding student experiences in the classroom [21]. In order to conceptually align the interview question with research questions [22, p. 813], and probe student experiences in a way that would “elicit conversation and stories, and [would] privilege participant perspectives” [23, p. 113], we followed guidelines from the IPR framework. We have successfully conducted qualitative interviews with students at two levels of resolution—following the completion of at least one lab to collect lab-level data and at the end of the course to collect summative course data.

In general, a clear interview approach is necessary to “place participants’ comments in context,” “check for the internal consistency of what they say,” and be able to “connect their experiences…against those of others” [21, p. 27]. The IPR framework is one approach to ensure that the interview is rigorously developed, conceptually aligned with the research questions, and that an inquiry-based conversation follows during the interview. Castillo-Montoya [22] outline four steps and suggested strategies to follow: 1) ensure interview questions align with research questions, 2) construct an inquiry-based conversation, 3) receive feedback on interview protocols, and 4) pilot the interview protocol.

Alignment: As we prepared to conduct interviews we were intentional to ensure focus on and coverage of the research question. We took inspiration from other qualitative interviews of online learning environments [24] and measurement instruments conceptually related to the research question [25] to generate potential questions for inclusion. We also disaggregated information from our research question—self-regulation, motivation, and the impact of online learning—to discern topics that needed to be addressed in the interviews. This step clarified our interest in both initial and ending levels of self-regulation and motivation, and general reflection on class experiences. We created a matrix, Table 1, to intersect interview questions with the research questions to assess “whether any gaps exist in what is being asked” [22, p. 812].

Table 1. Interview question matrix showing the connection of interview and research questions.

Question No.	Chronology	Initial Motivation	Current Motivation	Initial Self-Reg.	Current Self-Reg.	Class Experiences
IQ1	Pre-class	X		X		
IQ2	Pre-class					X
IQ3	Pre-class	X		X		
IQ4	Beginning	X		X		
IQ5	During		X			
IQ6	During		X		X	
IQ7	Overall	X		X		
IQ8	Overall					X
IQ9	Overall		X		X	
IQ10	Overall					X
IQ11	Overall					X

Conversational: The next step in IPR is to consider details to promote a climate that elicits detail and conversation from participants [22]. This process involves building rapport, thinking about the order of questions to ask, and leading into larger topics. Creswell and Poth [26] recommended that interview questions take the form of natural language, “phrased in a way that interviewees can understand.” In this context we moved away from the specific language of self-regulation and motivation, given the research-specific definition of these terms, to use language such as “approach,” “confidence,” or “interest.” As seen in Table 1, we also reflected on the time basis for each interview question here. To help participants reconstruct their class experiences [21, p. 90] and ease cognitive demand we organized interview questions chronologically. With that organization, interview question about pre-class conceptions were an induction to the process of describing beginning, during, and post-class experiences. In this phase we also designed transition and follow-up questions and a conclusion for the interview.

Feedback and Piloting: Several sources of feedback were used to shape the interview protocol. Beyond the feedback from developing the interview collaboratively, the interview protocol was shared with our broader research team to solicit feedback and ensure clarity in the plans. This conversation and our self-reflection were guided by a checklist adapted from [22, Table 4]. We did not pilot the interview with a separate population, but following the first interviews we debriefed to reflect on whether the interview protocol was effective, whether participant responses followed the topics we expect (i.e., that questions were clearly understood), and whether any improvements needed to be made. Completing even the first three phases of IPR are nonetheless “important steps to increase the reliability of their interview protocol as a research instrument” [22, p. 827].

Paired Thematic Analysis

Student interviews were conducted by Zoom across two semesters. Four student volunteers were interviewed partway through the course or at the end of the course using the protocol just described. We developed a qualitative coding scheme through inductive analysis of transcripts of these early interviews, which will be applied to analyze ongoing interviews about student experiences in online labs. Several strategies are being applied to support trustworthiness and dependability in the analytical process, including a collaborative approach to the coding process [27], and the development of a shared codebook [26]. While analyzing the interviews, language related to the concepts of self-regulation and motivation informed the generation of codes based on participants’ language. Two members of our research group familiarized themselves with the data and developed labels by consensus to represent dimensions of students’ experiences. These codes were refined with the inclusion of each early interview until new codes were no longer identified. Working together also supported a process of peer debriefing and reflexive writing while being immersed in the data [27].

Our reflexive writing was organized into a shared codebook, developed throughout the process to include the qualitative codes, descriptions, and examples of participant language. A codebook represents our shared understanding and can ensure stability in how codes are applied to future transcripts [26, p. 265]. One of the codes generated is excerpted in Table 2. These collaborative steps can be a challenge for the time they require, however working together has kept us close to the data and ensured an ability to communicate the meaning of students’ experiences [28].

Corroboration Via Latent Dirichlet Allocation

A final approach we have applied for early verification of this qualitative process (and as a form of analysis in its own right) is Latent Dirichlet Allocation (LDA). LDA is an unsupervised machine-learning-based topic model for analyzing textual data[29] – [31] which we have applied

Table 2. Example codebook for "Professional Skills."

Professional Skills Sub-codes: Time management, Re-checking Work, Collaboration/Teamwork	
Definition: Connections between laboratory experiences and various professional skills. Code for the appropriate sub-skill.	
Examples:	"*It's really easy, it being online, to feel tempted that you can just do something else during the lab time and them come back and do it over the weekend or some other day. I would just advise people to keep to the schedule, stay on top of it and not treat it just like a homework assignment that you can just put off.*" (Time management) *"I know I've had labs here that it's group labs here and two of the three people will go off on their own, finish everything and leave one person just stranded there not knowing how anything happened…. But with this one, [you have] to rely on your partner."* (Collaboration)

to participant transcripts to extract salient language from the interviews, similar to how themes are manually generated in traditional qualitative approach. Words that don't carry meaning (such as the, of, an) are removed from analysis and all remaining words are placed in a topic based on topic probabilities. Using a hierarchical Bayesian model, discrete data (words) in a document (transcripts) are analyzed to determine topic probabilities. The number of topics is adjusted and can be to determine the optimal number of topics necessary to represent a corpus of documents.

By identifying common words and patterns of associated language as it was used in the interview, our early work has been able to articulate dimensions of motivation and self-regulation in students' thinking about the course experience. For instance, one of the largest factors related to lab experiences was *questions and inquiry* (see Figure 1), where students highlighted that the needs for clear communication, help-seeking procedures, and structured time to ask questions were amplified in online instruction. Each of these relates to the concepts of progress monitoring and help-seeking in self-regulation. Elaboration of these results is forthcoming [blinded citation], yet the correspondence between these extracted topics and our manually coded themes offers reassurance about the rigor of our qualitative approach.

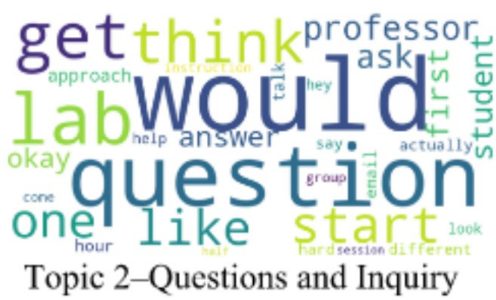

Figure 1. Word cloud generated from most frequent words used in "Questions and Inquiry."

Ongoing and Future Analysis

Though the circumstances that drove a shift to fully online learning are changing, these circumstances have catalyzed participation in online experimentation for faculty and students that might not otherwise have occurred. Indeed, we have seen integration of these online activities persist, even to augment more traditional modes of instruction including incorporation into pre-lab activities and assignment as post-lab "exploring deeper" activities. The interview protocol developed in the first step of our qualitative research has served as an important data collection mechanism that undergirds our analysis. Taken together with the researcher-generated codebook and LDA, we find support for the importance of self-regulation and motivation when participating in online experiential learning. We are continuing to explore student perspectives in rich detail using the interview protocol and new interviews are being analyzed with the coding scheme. We anticipate further insights as we move forward with paired thematic analysis, seeing perspectives and patterns that span the codes described here.

The qualitative strategies described here bring into focus students' experiences of participating in online laboratory instruction. However, this view is only one part of the larger ecosystem of online learning that also includes faculty and the usability of the learning platforms themselves, which can impact both faculty and learner success. Research in our larger project includes the investigation of these three perspectives (student, faculty, and user experience) in combination. Early results based on the comparison between the student and the faculty perspective show that there are similarities and also differences. For example, whereas faculty commented on the gained flexibility and the increased self-guided learning aspects in the online environment, students may miss that very guidance by a lecturer or teaching assistant in the physical lab. The preliminary results of the user experience thrust support that both students and faculty appreciate the flexibility afforded by the online environment. However, usability challenges in accessing just-in-time support and the steep learning curve using remote lab software create obstacles to learning for undergraduate engineering students. It will be important to understand those differing perspectives and incorporate them into the future designs of online laboratory settings.

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