"Never Met Them in Person, But We Help Each Other": Black Women's Experiences in Online Undergraduate Engineering Programs

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Abstract

In this empirical analysis, we provide a qualitative investigation of online learning among Black women engineering majors. This study makes theoretical and practical contributions by expanding knowledge of diverse online learners and informing ways to provide accessible and equitable online engineering education. Guided by the literature review, our analysis addresses two research questions: (1) How do Black women describe their online program learning experiences? and (2) How do participants describe their interactions with other students and faculty in their online programs? Using an exploratory, qualitative case study research design and the online collaborative learning framework, we analyzed interview data of 14 Black women students enrolled in online undergraduate engineering programs. The analysis of the data identified four major themes. Participants: (1) experienced isolation, (2) witnessed varying impacts of COVID-19, (3) observed the benefits and limitations of flexibility of online programs,

and (4) engaged in virtual connection-building. We conclude by discussing implications for higher education faculty and leaders.

Keywords: Black women, COVID-19, engineering, flexibility, online learning

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The underrepresentation of Black women is a major problem for engineering programs across the nation. In 2021, women across all racial groups represented only 23.6% of all bachelor's degrees in engineering and engineering technology (Roy et al., 2022). In the same year, a total of 1,808 Black women earned an undergraduate degree in engineering, making up less than 6% of all women who graduated with a baccalaureate engineering credential (Roy et al., 2022). When we compare these figures to the overall representation of Black women in the U.S. population (14% of women ages 15–44 in the United States are Black), we see that Black women's representation is not proportional to their representation in broader American society (March of Dimes, 2022). This gap in education access deserves scholarly attention. Moreover, during 2021, some 254 institutions in the United States awarded at least one engineering degree at the bachelor's, master's, or doctoral level (Roy et al., 2022). From these figures, the need to broaden participation and access for Black women in engineering is evident. One potential solution for this issue is greater use of online learning, which increases convenience and access to higher education. However, online learning may still be problematic, especially in its utility for Black women pursuing engineering.

More pointedly, in a rapidly changing higher education landscape, online learning continues to play a major role in content delivery. According to the National Center for Education Statistics (NCES) (2022), three-quarters of all undergraduate students (totaling 11.8 million people) were enrolled in at least one online course in Fall 2020. During the same semester, 7 million undergraduates learned exclusively online due to the pandemic (NCES, 2022). However, engineering courses can be particularly difficult to host online because they require practical lab experiences (Feisel & Rosa, 2005; May et al., 2023). Still, universities have expanded their online course offerings to compete for student enrollment and cater to the growing demand for online programs (Hamilton, 2023; Wiley University Services, 2022). Such expansion not only offers flexibility and accessibility to a wider student population but also demonstrates a shift towards embracing online education as a permanent fixture in higher education. To this end, a recent consent decree faced by UC Berkeley shows that accessibility and equity can be advanced through online learning materials (D'Agostino, 2022).

In this study, we focus on the lived experiences of Black women students in online undergraduate engineering programs at a large public university (LPU) in the United States. This focus is important because Black women are demographically underrepresented in engineering, which suggests inequitable access to higher education. Our goal through this study is to contribute to academic scholarship that will increase access to online engineering education for Black women. Moreover, based on recent studies on online engineering education and the racialized and gendered experiences of online learners during the pandemic, which are discussed in the subsequent section, we have identified a gap in the literature: online learning experiences of Black women students. Given the continued underrepresentation of Black women in the field, addressing this gap also has significant implications for practice and policy. Doing so will not only improve online program development in engineering for Black women but also influence policy making to achieve equity in postsecondary education access and retention and, ultimately,

workforce in the field. Therefore, we seek to expand the understanding of online learners by exploring online engineering learning during the COVID-19 pandemic through the cases of Black women students.

Literature Review

Online Learning and Equitable Pedagogy

Online education, which falls under the broader umbrella of distance education (in which the learner and instructor are physically apart; Roffe, 2004), is not new to higher education in the United States. Since the 1990s, the creation of the internet has paved the way for universities to introduce online educational programs (Kentnor, 2015; Martin et al., 2023). More importantly, because online learning utilizes computers and the internet to deliver at least 80% of course materials (Allen et al., 2016), it requires a different pedagogy from traditional in-person learning (Bernard et al., 2004; Archambault et al., 2022). When all modes of learning became virtual due to the outbreak of the COVID-19 pandemic, university students reported a lack of motivation and engagement and feeling of fatigue (Top Hat, 2020; Asgari et al., 2021).

More importantly, online education has revealed equity issues in higher education, such as the digital divide (Bell et al., 2022) and the education outcomes of minoritized students (Smith et al., 2024), and has brought opportunities to rethink and promote equitable pedagogy. Since the pandemic, scholars have discussed equitable digital pedagogy in various ways. Some of the strategies included providing technology access to students and redesigning curriculum to reflect their cultures (Ladson-Billings, 2021), "re-establishing norms," "using student names," "using breakout rooms," "leveraging chat-based participation," and "using polling software" (Reinholz et al., 2020, p. 7).

Racialized and Gendered Aspects of Cyber World

While much of the literature above focused on the overall impacts of the pandemic on students, other researchers have considered how gendered and/or racialized experiences might further impact online learning outcomes.

A number of scholars have focused on either the racial or gendered aspects of online learning experiences and outcomes. Britton et al. (2022) evaluated the gendered effects of the pandemic on undergraduate engineering students at New York University between 2017 and 2020 and concluded that women students experienced online learning more negatively than their male peers. Miller-Young et al. (2023) made a similar observation, in that women students tended to feel less belonging than their male peers in their first-year online team-based engineering course at a Canadian university. While these studies shed light on gendered experiences, Fletcher et al. (2023) studied engineering students from historically Black colleges and universities (HBCUs) during the pandemic. Their study revealed that HBCU students experienced academic and off-campus challenges while learning online. In addition to being unable to access faculty or advisors on campus, sudden changes in employment, finances, and family responsibilities negatively impacted their online learning.

Building on the discussion of racial/ethnic and gender identities in online learning, other researchers have sought to understand the experiences of those at the intersection of race and gender. For example, Zajac and Benton-Lee (2023) investigated the online experiences of minority students related to microaggressions. Their study highlighted that requiring a profile picture is a risk factor for inducing microaggressions for Black and Brown students. For example, women students of color felt invisible as their introduction threads online went ignored compared to their white counterparts who received comments. Additionally, their competence was questioned by peers. These experiences have been widely documented in face-to-face classrooms (Zajac & Benton-Lee, 2023). In addition, the authors found that participants often decided not to declare their identities, to protect themselves from online bullying and harassment.

Black Women's Learning During the COVID-19 Pandemic and the Black Lives Matter Movement

Regarding the racialized and gendered experiences of online learning, it is important to understand the broader impact of this study, which took place at the beginning of the fall semester of 2020. To this end, we discuss the recent literature on the Black Lives Matter (BLM) movement to understand its impacts on Black women's learning.

To situate the context of the study, we consider the activities of the BLM movement in the summer of 2020. People have shared their experiences of racism and marginalization using the hashtag #BlackLivesMatter since 2014, which surged in 2020, following the death of George Floyd (Egbuonu, 2020). More critically, Black women were going through racialized and gendered experiences due to the centering of Black men's experiences (e.g., the initial erasure of the murder of Breonna Taylor and the following campaign of #SayHerName) (Egbuonu, 2020; Pennant, 2022). Furthermore, Black college-aged women experienced fatigue and depression and did not want to draw attention in schools from being overexposed to racial microaggressions online (Tanksley, 2022). The pandemic also exacerbated Black women's economic trajectories by affecting their financial obligations, support, and stability (Porter et al., 2023). As evidenced by the literature, Black women's online learning experiences during the pandemic are especially unique because they were experiencing the intersection of race and gender due to the BLM movement while their offline lives were also suddenly transitioned online.

Faculty-Student Online Interactions as Barriers in Engineering

While online interactions in engineering have been considered as enabling flexible and diverse learning experiences (Bourne et al., 2005; Tremblay, 2006), they remain as barriers, especially in engineering. Even before the pandemic, online courses often provided few and less effective opportunities for faculty-student interaction.

Prior to the pandemic, researchers highlighted the lack of interactivity in U.S. online engineering classes. In online modality, they pointed out missing out-of-class interactions (Mackey & Freyberg, 2010), difficulty in teaching and learning through graphic information

without rich communication (Kinney et al., 2012), and the impact of asynchronous remote instruction on faculty and student interactions (Gary et al., 2017).

More recently, post-pandemic studies have continued to reveal limitations of online interactions in the field. Students experienced the loss of hands-on activities and engagement when their lab-based engineering courses were moved online (Johnson & Barr, 2021) and went through "Zoom fatigue" (Asgari et al., 2021, p. 6), which is the feeling of exhaustion due to taking classes on Zoom.

Overall, prior research has substantially investigated the online learning experiences of the engineering student population during the pandemic. However, there are relatively few studies on how the students' gendered and racialized experiences intersect. Meanwhile, there has been extensive research on Black women (Ross et al., 2017; Ross et al., 2021) and Black men (Burt et al., 2019, 2021) in engineering, and yet, the online aspects of their engineering education have not been adequately understood. The climate in science, technology, engineering, and mathematics (STEM) is often referred to as chilly (Flynn, 2016; Parson & Ozaki, 2017) for Black women due to their racialized and gendered experiences. Despite the existing research on the challenges faced by Black women in engineering, there is limited knowledge about how these experiences translate into virtual learning environments.

Our work is critical because we take a deeper look at Black women students' online program experiences in engineering. Through this study, we aimed to understand Black women students' overall online program experiences and their interactions with peers and faculty using the online collaborative learning framework, which provides us a new lens for looking at minoritized students in online settings.

Conceptual Framework

In this study, we use the online collaborative learning (OCL) framework. OCL is a theory of learning, which focuses on the learning environments that foster collaboration and building knowledge collectively (Harasim, 2012). It is anchored in the idea that students learn by talking to one another and co-constructing a solution to a problem, rather than memorizing correct information. Per OCL, there are three phases of knowledge construction through discourse: (1) idea generating, (2) idea organizing, and (3) intellectual convergence. Harasim describes OCL as a new theory of "learning that focuses on collaborative learning, knowledge building, and Internet use as a means to reshape formal, non-formal, and informal education for the Knowledge Age" (2012, p. 81).

We draw from the following tenets of OCL in this study: The learning environment and learning interactions as the context of our study is entirely online (see Appendix for interview questions that tie to each tenet). OCL integrates conversational learning, conditions for deep learning, development of academic knowledge, and finally, joint knowledge construction. The end goal for the theory is to make inferences and apply them under different circumstances. According to this theory, learners start the process of generating, organizing, and converging on

ideas at a more advanced level, which is facilitated by professors through instructions and pedagogies (Harasim, 2012).

OCL is a fitting theoretical framework for our study because of its past applications on related research studies. For example, McCollum (2020) has shown how this theory can be used in synchronous and asynchronous STEM courses. In addition, the framework has been utilized to design and capture online collaborative learning in cross-cultural and multicultural settings (Kumi-Yeboah et al., 2017; Kumi-Yeboah, 2018). Specifically, it helped capture minoritized students' comfort in leading online discussions and magnified cultural differences in online settings due to the lack of engagement with cultural diversity and inclusion in curriculum and reading content (Kumi-Yeboah et al., 2017). However, to our knowledge, we are the first to apply OCL to better understand the experiences of Black women in online engineering programs.

Purpose and Research Questions

The purpose of this study is to understand Black women students enrolled in online undergraduate engineering programs. Our research questions stem from the literature review on Black women's learning during the pandemic and online interactions in engineering. Accordingly, the guiding research questions are: (1) How do Black women describe their online program learning experiences? and (2) How do participants describe their interactions with other students and faculty in their online programs?

Methods

We used a qualitative exploratory, case study research design to collect data for this project. In this section, we provide additional details about participants, the data collection instrument and collection procedure, and the steps taken for data analysis. IRB approval was obtained.

Participants

As illustrated in Table 1 below, the participants in this study were 14 undergraduate students attending a large public university in the United States. All participants self-identified as Black women. Most women pursued majors in the field of information technology: Three studied information technology and four, graphic information technology; the rest were studying electrical engineering (3), software technology (2), engineering management (1), and web development (1). All participants were assigned pseudonyms. Black women participants were recruited via a one-page digital flier circulated via email to faculty, staff members, and students. The flier included a link to a 10-item recruitment Google questionnaire. The recruitment form asked each respondent to share their name, email address, enrollment level (undergraduate or graduate), expected graduation year, major, and other demographic information (e.g., birthplace, citizenship). This information helped us screen prospective participants. After a prospective participant completed the survey, a member of the research team (usually the study's Principal Investigator) would email the individual to schedule an interview time. The recruitment Google questionnaire was provided to all who showed interest in the instrument, and some individuals

who completed the questionnaire did not go on to participate in the study. All individuals who participated in the study were offered a $50 participant incentive via a cash transfer app (e.g., Venmo, PayPal).

Table 1
Participant Background Information

Pseudonym	**Academic Major**	**Primary Aspect of Online Learning Appreciated**
Andrea	Information Technology	Flexibility
Angellina	Information Technology	Campus resources
Brenda	Software Technology	Flexibility
Bristol	Web Development	Flexibility
Charley	Electrical Engineering	Program culture
Griselda	Graphic Information Technology	Campus resources
Jess	Graphic Information Technology	Course discussion
Laken	Engineering Management	Campus resources
Lauren	Information Technology	Course content
Lilian	Graphic Information Technology	Flexibility
Oakley	Software Technology	Course content
Reese	Electrical Engineering	Flexibility
Sharon	Graphic Information Technology	Caring faculty
Stacy	Electrical Engineering	Flexibility

Instrument

The demographic information of the participants was collected through the recruitment form; thereafter, we conducted semi-structured interviews with each participant. The primary data collection instrument was a 31-item interview protocol based on external literature and informed by expert review (see Appendix for the full protocol). The protocol was divided into four sections that focused on different variables, including: (1) departmental culture/campus supports; (2) personal identity; (3) academic support, classroom interactions, and mentorship; and (4) professional development and career goals.

It is important to note that we did not draw from OCL when designing the interview questions. Instead, we drew from OCL tenets in the data analysis process to make sense of the qualitative experiences of Black women in engineering. OCL helped us zoom in on how participants experienced knowledge building and interactions virtually in online degree programs.

Data Collection

The researchers collected qualitative data over a five-week period in the Fall 2020 semester. All interviews were audio-recorded over Zoom and then transcribed verbatim using a commercial transcription service.

Data Analysis

Data were analyzed in four distinct steps. In the first step, we reviewed the qualitative codebook compiled by a research team member by organizing codes such as academic major, perception of experience in major, interactions with other students, impact of the COVID-19 outbreak. Reviewing this codebook allowed us to identify constructs of interest. Next, the authors reviewed participants' demographic information and researcher memos. During this stage, we also had iterative conversations about the compelling elements of this data set. The third and fourth step involved two cycles of open coding. In the first cycle of open-coding, the authors re-read each transcript and conducted line-by-line coding. In the second cycle, the authors identified components of the interview transcripts that addressed the research questions. Cumulatively, these steps helped us arrive at four themes that characterized online learning for Black women engineering majors, which are discussed next.

Results

In this section, we present the four themes that described how Black women students experienced their online programs in different majors within engineering. Of note, information on participants' academic majors can be found in Table 1. Based on the analysis of the interview data, we identified that our participants: (1) experienced isolation, (2) witnessed varying impacts of COVID-19, (3) observed benefits and limitations of flexibility of online programs; and (4) engaged in virtual connection building.

Experiences of Isolation

Most of our participants reported learning in isolation due to the nature of their enrolled online programs in engineering. Participants articulated that they felt isolated because of limited opportunities to interact with their peers. They often missed the day-to-day peer interaction component in their learning environment, and often stressed the fact that they never really met their peers. However, most participants reported the class projects to be collaborative and team-centric where everyone's input was needed.

Lack of Interactions

Overall, participants expressed how they had limited opportunities for networking with peers. For example, Reese explained this when she said:

> Since I'm an online student, I haven't really interacted with any students at all. Any other students other than . . . I think in the beginning of the semester, we would have the discussion boards, introduce yourself to your other classmates. But other than that, I haven't interacted with any other student.

Bristol echoed experiences with isolation. She mentioned that most of her interactions were isolated. The interviews for the study were conducted in the fall of 2020, as the BLM movement had a resurgence across the country. During those times, she mentioned missing out on interactions with others, especially Black students. Oakley also characterized online learning as isolated. She mentioned her experience of being a Black woman in engineering spaces; however, her quote captured the isolation components of an online setting.

> Well, I guess it's kind of hard for me because I'm online and so you're not physically in a room with the teachers and the students. Everyone pretty much sees the one little icon picture that you have on your profile.

Talking about her experiences in a mathematics class, Oakley highlighted that she had to depend more on external sources to learn than on the lecture itself because they were not interactive.

> I guess the explanation and the lectures aren't as interactive as were needed for some of the students to do well in the classes. And I felt that way too, especially with some of my second and third calculus classes. I feel like I relied heavily on a lot of outside sources versus some of the lectures.

The interview data show that the online format missed capturing the interaction from peers even virtually. Also, the classes lacked the interactive components to a point that students relied on outside sources. The lack of these interactive components, which often requires students to pursue learning experiences beyond what the course offers, increases their sense of isolation.

Sharon reiterated the need for opportunities to connect with other women students, especially Black women students:

> I have not seen another Black woman in my courses. Maybe I've just like taking them in a different semester but I haven't had that privilege to really connect with anyone. I think

> there was a girl that was Mexican in one of my classes but as far as Black women I really would like to be able to connect with other ladies.

This sentiment was shared by Oakley, Bristol, and Andrea. Specifically, Andrea explained the importance of peer networking with other women:

> I do find more comfort in working with females and especially Black females because we can of course relate to each other more about different things. And males, sometimes, don't get that. They just want to take control and tell us what to do.

Andrea's statement highlighted the male-dominated nature of the engineering discipline. Her interview data imply that she perceived working with women easier than working with men.

Additionally, the data show that students experienced lack of faculty interaction due to virtual format. Many participants echoed the significance of pedagogies embraced by faculty. For instance, Sharon shared that while there were professors whom she got to know very well, there were those whom she did not know due to the online nature of the classes.

> I think on the faculty side, the professors that I've really gotten along with are professors that are more dedicated to helping students in general. It's like they have a different mindset. I have had really two professors that were just phenomenal. And when I think about the two is that they really want students to succeed. And then I have another group of professors that I couldn't tell you much about them. Not that I didn't attend their class is just because they didn't teach the class, but you have a video recording taught by another professor and they give you feedback. And even with giving feedback, a lot of times it's a student grader that's giving the feedback.

Counterintuitive Reflections on Isolation

On the contrary, Stacy's experience of isolation showed a stark difference from her peers as she enjoyed working by herself.

> I'm a pretty secluded person. So the online environment is comfortable for me . . . I like working by myself. I don't really like collaborative work, but I have ended up in a project before, and it's just something that you end up getting used to, especially if you're online or anything like that, but online actually, I haven't had that many collaborative work unless I was in like a humanities course.

This quote from Stacy suggests that some students may, to some degree, appreciate being able to work by themselves. In addition, Stacy does not seem to expect collaborative learning experiences outside of the social sciences and humanities.

Moreover, it was also interesting to examine more closely the participants who did not engage much with peers in or outside of class time. Among such participants, Oakley mentioned that if she were interested, she would have participated in study groups. Meanwhile, she

described herself as "an introverted learner" and "a self-learner." Similar sentiments were shared by Charley, Griselda, and Stacy. Stacy, in addition to her preferred solitary study habit, elaborated that while she was part of "a lot of group chats," she did not actively participate in study groups because of her negative experience with male students. In her occasional engagement with study groups, Stacy felt that men students did not take women students seriously, especially Black women.

Varying Impacts of COVID-19

When asked about the COVID-19 pandemic's impact on their academic and professional journey, our participants voiced different stories. Griselda, Lilian, and Oakley stated that their academic journey was not "really" impacted. While Griselda did not elaborate on her response, Lilian added:

> Academic journey, no. Only because I've been out of school for a while so it didn't really make a difference. And now we're in what, month nine of the pandemic so I think I just leveled everything out and it is what it is at this point.

This sentiment also resonated in Oakley's experience. She explained that unlike in-person students, her academic journey "didn't change much . . . Everything is pretty much the same" because she was an online degree student. Also, her work was "partly remote half of the week," which seemed to further account for why she did not experience many changes during the pandemic. Interestingly, although both Lilian and Oakley described little impact from the pandemic, they identified different explanations of the shared phenomenon. Lilian attributed this to being "out of school for a while," whereas Oakley perceived it as the result of being an online student.

In contrast, Brenda specifically highlighted the changes the pandemic brought to her experience as an online student. She described her classes as "rushed and unprepared" and without "individual attention" because, for example, one of her classes "had 400 to 500 students online." Given that her classes had 300 students before the pandemic, this represents a critical shift not only in the number of students in classes but also in a faculty member's capacity to interact with all the students.

For other students, the pandemic affected their in-person interaction and learning outside their academic programs. Specifically, four students described how the pandemic significantly affected their ability to network with people and have face-to-face interaction. Sharon summarized her experience: "COVID-19 really was an isolation cue. It's just like, here's the little box that you have to stay in now, on to everything." Similarly, Angellina's internship transitioned to online, making it impossible for in-person interaction or learning. Stacy and Sharon also experienced interruptions in interview opportunities. Jess experienced high stress due to her health vulnerability and frustration with being unable to work hands-on.

Observed Flexibility

The pursuit of online studies is associated with a flexibility not traditionally afforded to students through in-person learning. The modality of online programs enables participants to essentially be in two places at one time. As a result, participants with caregiving duties may attend classes while caring for their dependents. Reese, mother of a newborn baby at the time of the study, was juggling the demands of coursework and other life roles. As she recalled:

> Right now, it's been really hard with having a new baby. So, I actually am with him all day and he goes to bed at about 7:30 PM and I'll study from 7:30 PM until 1:30 AM. So, it's difficult . . . And I'll try to squeeze in studying in between his naps and stuff like that throughout the day, but that's pretty much what I do every day. Even on the weekends, I'll still study just to make up for the time I lose during the day.

While the juggling is described by Reese as "difficult," taking classes online enables her to physically be with her baby as needed. One can sense the challenge of "juggling" these responsibilities as articulated by Reese. However, were she enrolled in in-person classes, it would limit time with her baby on a daily basis. Additionally, Reese would have to identify an alternative caregiver for her baby, which could result in an added expense. The availability of online studies reduces potential strain on other roles held by the students (e.g., caregiving)

For other participants, the modality of online studies enabled them to simultaneously pursue multiple opportunities. Oakley, a full-time student, worked a full-time job in addition to her student responsibilities. It is plausible that without the modality of online classes, it would not be possible for Oakley to simultaneously be both in her work environment and in a classroom. The same hypothetical was made real for Lilian, who held a job at a large corporation that beneficially offers a tuition partnership with the LPU. Lilian explained

> Yeah, so, the [redacted corporation name] program has a whole separate team, separate from LPU that deals with specifically [redacted corporation name] partners which I really appreciated . . . I was in contact with a [redacted corporation name] partner hub that relates to [LPU-corporate partnership program], so that was definitely really helpful. And then once I started my classes and I found out there was a whole team that I could contact, that was also helpful. But the fact that there's a whole system dedicated to just [redacted corporation name] partners, because it's different when you're going to school online and you're working, I definitely appreciate that.

In her excerpt, Lilian refers to the resources available to her through her job that supported her ability to take classes online. The flexibility of her online learning was further strengthened with a corporate partner being connected, which established resources for her and other employees to leverage as online learners.

While the benefits of online learning flexibility were apparent in the stories of some participants, others did identify some limitations. Among them, Brenda mentioned the challenges to flexibility presented by online learning. She explained:

> It's really weird because for online classes, most of them, they only let you take an A or B session, which are seven weeks long. So, it's like a 14-week course crunched into seven weeks. I have to have two classes for A session and two classes for B session. So, it adds the stress on of trying to stay caught up with homework. I don't understand why they do that. I wish they just offered C sessions for us, like everyone else.

Brenda acknowledges the challenge of taking short, intensive courses. It is clear from this quote that Brenda is frustrated by the pacing of online courses.

Virtual Connection Building

While many of our participants felt isolated due to the online nature of their programs, online tools and technology enabled some students to make connections with their peers virtually and even build an online community outside of classrooms. For instance, Angellina, who was doing an internship at the time of her study, described her daily interaction with another online student from Vietnam:

> Yes. I interact, actually, with one [student]. She's from Vietnam, but now she's a U.S. citizen. I interact with her on a daily basis. We worked on projects together because we ended up having a lot of the same courses. In fact, we worked on our capstone project together, too. And then we have, besides that capstone course, we have another course together. Like the last session we had all of our courses together. So, I talk to her on the regular. And some of the things that I've taken, she hasn't taken yet and vice versa. So, we help each other out.

Angellina and her peer seemed to have cultivated a nurturing relationship in which they shared their courses and projects while helping "each other out." Her story illustrated a one-on-one relationship building that extended outside the classroom. Similarly, Brenda discussed how she formed "a study buddy group" to get help on her classes and exams. Below, she explained how she took the initiative to find the group.

> Well, what helps me is in my classes, I find a study buddy. So, I have a study buddy group of about three people now. So, we practice together, and we'll make study guides before we take quizzes or midterms or finals. So that is super, super helpful. I feel like I'm not a very good test taker. So I know what I'm talking about.

In addition to the available campus resources, Brenda created her own community that further supported her academic success. As she continued to talk about her classmates, her story

highlighted a proactive act of community building, which seemed to have come from her shared sense of solidarity with peers. In the next excerpt, Brenda emphasized that she and her classmates helped each other out even though they had "never met [each other] in person" because they were "on that same track."

> I have a few people that I've taken classes with online, never met them in person, but we help each other out because we're on that same track. We're not always taking the same classes at the same time, but sometimes we're like, "Hey, have you taken this yet?" Or "When do you plan on taking this?" So that we are able to help each other out if need be.

Virtual connection building also resonated in Lauren's and Jess' experiences. Their experiences were a bit different because they were able to adequately interact with classmates in the existing course format with the help of instant messaging applications. Lauren, a self-employed student, related that one of her classmates created a "GroupMe" that allowed them to talk more. GroupMe (2023) is a mobile group text messaging app known for its accessibility for team collaboration. While Lauren perceived that there "wasn't a lot of interaction," she stated that it was "more than just the normal discussion board interaction."

> I have talked to a few, because of the discussion boards that my courses require. I'll end up having discussions and then we might end up talking about off topic things. One of my classmates, she created a GroupMe (chat), which allowed us to kind of talk a little bit more, but it wasn't a lot of interaction, but it was more than just the normal discussion board interaction that spilled over into the group.

Similarly, Jess, who was a single parent of three children working full-time in the Air Force, brought up her class discussion experience with Slack. Slack is an instant messaging program like GroupMe that needs to be created on a team level and can be controlled by administrators (Ivanova, n.d.), in this case, by the LPU. Jess highlighted her positive experience with Slack:

> So, a lot of our classes will have discussion boards and things like that. I think that my favorite thing was Slack. If every class used Slack as far as online, that would be great because that became almost like you're texting everyone, not logging on some Blackboard and doing a discussion, but in real time. I think the best thing about it was that the professor put examples up not on Blackboard but on Slack. Because if I was having an idea moment, I can go back to Slack and say, hey, this is going to work, and see the examples. And then other people, once we were working through our processes, we put it on there and then other people would come in and we'd comment on each other.

For Jess, Slack allowed her to talk to her professor and classmates in "real time," which thus facilitated connection building. In addition to having discussions via Slack, her professor's use of Slack to share course materials further benefited her. As her professor posted course examples in Slack instead of Blackboard, the usual platform for class discussions at the LPU, Jess was able to

access them easily as she reflected on her ideas and coursework. This messaging program promoted more active interactions among online students because they were able to share their work and provide feedback there

The examples from Angellina and Brenda show how online students took initiatives to extend their interaction and relationship building beyond the required course engagement and discussion boards. Then, Lauren and Jess highlighted the extent to which they were able to increase their engagement with peers within their course organization by using technology applications. Overall, online learning experiences often led to a feeling of isolation. However, the online environment provided a platform for students to support one another in and out of their formal learning environments.

Discussion

As an exploratory study, our paper helps to fill a research gap on the experiences of Black women students in online engineering programs by shedding light on their experiences at LPU. While our findings do not explicitly reveal racialized aspects of their experiences, they are situated in the work of many other scholars who have shown that women of color navigate hostile educational spaces and discriminatory practices in engineering (McGee, 2020; Parson & Ozaki, 2017). Specifically, our study expands the discussion on Black women engineering students' feeling of isolation in White spaces and need for counter spaces that are safe spaces for minoritized students (Blosser, 2020) by showing how isolation is experienced in online modality (Sung & Huang, 2024) by Black women. Participants highlighted their limited peer interactions, specifically with other women students in their online engineering programs. In relation to isolation, they also underscored the importance of faculty in fostering (or lack thereof) interactive components in online courses. Furthermore, this study shows how gendered educational experiences unfold in engineering for Black women students. The findings contribute to literature that shows how the COVID-19 pandemic encumbered learning (Harper, 2020). The results emphasize the key advantage of online learning, which makes room for students who may also have caregiving responsibilities or full-time jobs. Previous scholarship has shown that women of color must often balance caregiving with learning, and online learning may be a way to achieve educational access and equity for this student group (Sampson, 2020). Based on the fourth finding, we see that core social group formation and engagement involves classmates and peripheral relationships are made possible because of the online modality and technology. Online classrooms and engagement serve as a launch pad for Black women students to build connections, and even a community, outside classrooms. This finding is especially crucial for making online course formats more accessible for, and supportive of, Black women, who often do not have opportunities to interact with other women or Black women in online engineering programs. Thus, our study extends the literature on advising online students that highlight the importance of supporting their connection building through communication, relationship building, and support in personal and academic growth (Meyer et al., 2022).

When thinking about the application of OCL to our study site, participants experienced community building in an online space, which is a form of communities of practice. Because of OCL's emphasis on idea generating, idea organizing, and intellectual convergence, OCL underscores that institutions such as LPU must be intentional in the consideration of what online engagement looks like, how it is facilitated, and how to assess and/or ensure that online education is not at a detriment to the student. For Black women, as several participants discussed the negative perceptions of men toward Black women in online classes and their impacts on working with other students, LPU needs to take into account these race/gender dynamics among online students and redesign online engineering programs to enable positive virtual connection building in and outside of the programs. Finally, OCL helps us consider the implications of teaming as a critical component of most engineering thinking and learning. Thus, faculty designing online courses should carefully consider what content can truly be optimized through an online setting and how to deliver this content while providing opportunities for collaboration, especially for historically underserved communities (Bourne et al., 2005; Dziuban et al., 2015; Herman, 2020).

Overall, our study demonstrated that online Black women students undergo a unique experience of online education consisting of both isolation and virtual connection building. We understand that the Black women students reported isolation at large because they were enrolled in an online engineering program even before the pandemic. While students experienced increased flexibility and formed virtual support groups on their own, they often did not have institutional support for faculty and peer interactions. Due to the fully online modality of their degree programs with heavily lab-based engineering courses, these issues around isolation and interactions need to be addressed in ways that do not mimic the structure and delivery of in-person programs or classes.

Based on our findings, online engineering programs should be designed and structured in ways that leverage the technology and modality optimum for Black women. For example, institutions should take accountability for connecting Black women with their peers, to form a sense of solidarity and friendship in virtual counterspaces, especially with other women of color. Moreover, with the recent development of artificial intelligence and virtual reality technology, online programs should build in more interactive and immersive components with an understanding of Black women students' needs and contexts.

These findings are important because our work makes both a theoretical and empirical contribution to literature. Theoretically, this study contributes because we are the first to apply OCL to better understand the experiences of Black women, specifically drawing from the two tenets: the learning environment and learning interactions. With the help of professors online, the students in our study generated new ideas and constructed applications of engineering. The learning environment refers to tools used during the classes (Zoom) and for interactions (GroupMe and Slack chat). In terms of our empirical research contribution, our study shows that there are nuances of using technology and that even though students often needed to take initiatives outside of their formal online learning environment, online platforms and tools helped

them connect with others virtually. Also, our analysis extends the application of the OCL framework to study Black women students in an online setting.

Limitations and Delimitations

One limitation of this study is being a single-site study. We recognize that the themes we see in the data might be hallmarks of LPU's online engineering programs, as opposed to these programs at large across U.S. higher education institutions. To address this limitation, future studies should explore other institution types.

Another potential limitation is the timing of this study. Our data were collected during a time of external stress due to the COVID-19 pandemic. Also, as discussed in the literature review section, Black women were going through racialized and gendered experiences due to the pandemic and the BLM movement (Pennant, 2022; Tanksley, 2022). As such, if the study took place at a different time, isolation might not have been felt as strongly by the participants. While we observed varying impacts of the pandemic on students' academic and professional experiences in our findings, it is important to note these various ways the BLM movement affected offline and online lives of Black women students. Accordingly, as argued by Pennant (2022), our participants' stories are embedded in their multi-layered experiences of multiple pandemics (i.e., the COVID-19 pandemic and BLM movement), which may manifest differently in other non-pandemic time periods.

Recommendations for Future Research and Practice

The data from this study suggest a need for synchronizing and systematizing resources. Namely, resources should be designed for specific engineering disciplines, not only to provide technical assistance but to facilitate group interaction within and across programs. Online degree programs offer the same academic resources as in-person programs and only provide technical assistance related to online courses. This is concerning, given the reported lack of help specific to the Black women students' majors and across online engineering programs and the missed opportunities for networking and interactions. Thus, it is essential to understand the diverse contexts and needs of online Black women students, which might be different from other Black women students enrolled in in-person degree programs.

Moreover, as shown in the study, we acknowledge that the need for online courses might be different for online Black women students. For example, some participants preferred studying alone and many had competing responsibilities, such as caring for children and working full-time. As such, this further warrants a closer look at these students' contexts. Accordingly, university administrators and leaders should recognize the experiences of Black women students and provide funding for major-specific resources across online engineering programs.

For designing and facilitating an online learning environment for Black women students, the practices of LPU professors could be a potentially useful example for engineering faculty at other institutions, based on our participants' positive narratives of faculty interactions. In addition, higher education faculty should try to optimize online education for online modality.

Black women students in online degree programs do not want an online learning experience to be a replacement of the in-person modality but need support that is specific to their context and needs as online students who navigate racialized and gendered aspects of online education.

Future research should also investigate online engineering experiences across various racial groups, gender, and other identity markers. Moreover, future researchers may consider incorporating social and emotional support for distance learning. For example, past researchers have crafted the Inclusive Student Services Process Model framework that proposes identifying strategies across diverse phases of student learning to indicate where and when they can be delivered to online students (Rotar, 2022). The complex experiences of our participants show that inclusivity needs to be an integral part of engineering learning futures at different institutions.

Closing Remarks

Our study focuses on the lived experiences of undergraduate Black women students in online engineering programs. Based on the findings, we conclude that, on the one hand, these students experienced isolation, especially during the pandemic and BLM movement. However, due to the flexibility of their online programs, students managed various other roles while being full-time students. They also engaged in building virtual connections with peers and faculty with the help of online modality and technology. As a result, this study contributes to theory and practice by utilizing OCL as a lens to understand Black women students' online learning in engineering and adding knowledge of their unique experiences to improve access to and equity in online engineering education. Higher education leaders should design online engineering degree programs in consideration of these experiences and learn to further support online Black women students to pursue their education in diverse contexts.

Conflict of Interest Statement

The authors do not have any conflicts of interest to declare.

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Appendix

Interview Protocol

Note: Questions that tie to OCL tenets are as follows:

- Learning environment: 2–3 in Section 1; 3–4 in Section 3; 5–7 in Section 4.
- Learning interactions: 5–10 in Section 3; 1, 5–7 in Section 4.

Google Form

1. Have you had a chance to fill out the Google form? Yes, or no?
    a. If not, I'm going to just quickly fill in the information (ask questions aloud) and fill in Google form.

Section 1: Departmental Culture/Campus Supports

1. What first made you interested in this major?
2. Do you enjoy being at the engineering school?
    a. Do you feel welcome?
3. Do you like this university?
    a. How would you describe the culture of your program/department?

Section 2: Personal Identity

1. How would your best friend describe you?
2. Is your race important to your identity? Why?
3. What about your identity as a Black woman specifically? How important is that?
    a. What about your culture and/or language?
4. Do Black students have a different experience here, compared to non-Black students?
    a. What about Black immigrant students?
5. Are you the first to major in engineering in your family?
6. How would you describe your socioeconomic status?
7. Do you have other identities or responsibilities off campus that you often consider in your life, outside of your identity as an undergraduate student? If so, what are they and how do they impact your ability to continue in engineering?
    a. For example, responsibilities to family members working 20+ hours a week, commuting from home, etc.

Section 3: Academic Support, Classroom Interactions, and Mentorship

1. What academic services available on campus positively assist/support you (tutoring, advising, etc.)?
    a. How often do you use these services?
    b. What supports/services do you wish were present at either the department level or the institutional level?
2. What was the transition from high school to college?
    a. Could you tell me more about your experiences in your introductory math and science courses?
    b. Could you tell me about your experiences in your introductory engineering courses?
3. Describe your ideal learning style. How does this preference vary from lecture based to laboratory courses, to project-based courses?

4. How would you describe your study habits? What enables you to best perform on exams/various forms of assessment? Would you say your abilities are accurately reflected in your assessment outcomes?
    a. Do you study with other people? If you study by yourself, do you have groups that you could potentially study with? How did you form these study groups?
5. Describe your interactions with other women students in your engineering classes.
    a. Are there other Black women in your class? How is interacting with non-Black women in these classes?
    b. To what extent are interactions with women of color/women who are 1st/2nd generation immigrants similar or different from women from racial majority groups?
6. Did you have engineering faculty (including Teaching Assistants) that identified as women? If so, was your relationship/interactions different from your men professors?
    a. How has that experience influenced your learning?
    b. How has that experience influenced your sense of belonging in engineering?
7. Do you have any friends in your major? What is your friend group like?
8. To what extent have your interactions with faculty, staff, and and/or students outside of your engineering program (but on campus) impacted your experiences?
9. Do you have any women mentors (can be students too) within the university? How did this mentorship start?
    a. Do you have any mentors in your career field?
    b. How have your mentors shaped your academic and career interests?
        i. What are their races?
    a. Do you have any women mentors outside of the university?
        i. What are their races?
    b. Do you have any Black mentors?
        i. What are their genders?
    c. Do you have any immigrant mentors? Where are they from?
    d. Do you have any mentors who are not from underrepresented groups?
10. What do you wish your professors knew about you that you don't think they know? What about your classmates?

Section 4: Professional Development and Your Career Goals

1. What professional opportunities, if any, have you had to gain exposure to the field of engineering (i.e., conducted an internship, study abroad or performed research in a lab, etc.)?
    a. To what extent have you had the opportunity to take on leadership positions on campus in general or within engineering in particular?
2. Which opportunities have you had to travel abroad as it relates to your undergraduate experience (i.e., research study abroad, Engineers Without Borders, etc.)?
3. Do you see your career/employment/academic trajectory in the next 5 years?
    a. What do you foresee will be the biggest hurdle toward reaching that goal?
    b. What do you see as your greatest assets for reaching those goals?
4. Do you feel the impacts of financial pressures—like loans or debt?
5. What about the COVID-19 outbreak?

6. Describe a time where you felt like an engineer.
7. Describe your greatest challenge in your pursuit of engineering.
8. What advice would you give a Black (immigrant) woman who's about to start going here?
9. Imagine that you were an administrator with the authority (and unlimited budget) to implement a policy or program to support Black (immigrant) women to be successful in their majors? Describe a change you would make?
10. Has anything come up that you would like to revisit or anything else you would like to share?