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Reducing Access Barriers: Exploring Student Smartphone Use Across Higher Education Institutions

Alex Rockey, PhD
Bakersfield College, Bakersfield, California, United States
iD https://orcid.org/0000-0003-1170-038X

Jenae Cohn, PhD
University of California—Berkeley, Berkeley, California, United States

Samantha Eastman, M.Ed.
University of California—Riverside, Riverside, California, United States

Contact: *alexandria.rockey@bakersfieldcollege.edu*

Abstract

With near ubiquitous smartphone ownership among 18–29-year-olds, many students carry mobile technology everywhere they go, yet little is known about how students use mobile devices for learning. For historically marginalized students, in particular, their phone may be an important tool for learning—especially if it is the primary device used to access the internet. This study explores student perceptions of using mobile devices for learning in focus groups with students from a California community college, a California state university, and a California university. Findings suggest that students often rely on their mobile devices as both an emergency bridge and to make progress on coursework in the in-between moments of their day. However, students also note frustration with using mobile devices due to limitations of small screens and challenges with accessing course content or completing assignments. Implications of this study highlight the importance of faculty development on designing mobile-friendly courses to empower students in leveraging their mobile devices for learning.

Introduction

The myth of the "traditional" student who attends a residential 4-year institution, lives on campus, and has no external job (besides studying), no longer represents the majority of students served in higher education (Nguyen & Kramer, 2023; Remenick, 2019). Today's college student, regardless of whether they attend a

residential 4-year college or a community college, is juggling many responsibilities outside of school, as well as demands on their time, including child, sibling, elder care, long commutes, and/or jobs. While students may be juggling multiple demands on their time outside of coursework, higher education remains one of the most important pathways out of poverty. As the number of people living in poverty continues to increase in the United States (U. S. Census Bureau, 2021), students need access to high-quality education now more than ever.

Given the pervasive access to smartphones—often regardless of socioeconomic status (Pew Research Center, 2021)—they are a crucial tool to supporting equity in higher education and increasing access to high-quality educational offerings. Smartphones can help eliminate access barriers, especially if access to home internet is limited.

Across the United States, access to home internet varies based on income, age, and ethnicity (Pew Research Center, 2021). In college today, students need to have access to the internet to complete assignments, conduct research, and complete readings necessary to be successful in a course (Elliot, 2022). In fact, the Pew Research Center (2021) found that 28% of 18–29 year olds are dependent on their smartphone for access to the internet. Furthermore, a disproportionate number of those who are smartphone-dependent are from minority populations (Perrin, 2021), which widens equity gaps in teaching and learning.

Research has explored what devices students own and has demonstrated near-ubiquitous ownership of smartphones (e.g., Elliot, 2022; Perrin, 2021; Pew Research Center, 2021), which can provide students without home internet a way to continue working on coursework or assignments after the day ends or after the library closes. The accessibility, portability, and speed of smartphones allow students to complete coursework outside of the home and **during "in-between" times of their day** (such as during a commute), which may give them uninterrupted and private time to work.

Being able to leverage the in-between moments of a day for coursework is especially important for today's college students who are balancing multiple demands on their time. Finding extended periods of time to work on coursework uninterrupted can be impossible for students balancing long commutes, childcare/elder care, and/or multiple jobs. However, leveraging the 10-minute chunks in a day, such as after kids go to sleep or while cooking dinner, can be an important opportunity for students to continue to make progress towards their degrees while juggling multiple demands on their time.

There is a need for research that explores *how* students choose to use those smartphones for accessing course content and completing coursework (Milheim et al., 2021), however. Understanding how students prefer to use their smartphones for learning provides important insight into how we can effectively design courses and learning experiences to leverage the technology our students already use. Intentionally leveraging smartphones, as part of learning experiences, helps increase access to high-quality educational opportunities and effectively provides pathways for students to earn a college degree.

Literature Review

Smartphones are tools for digital equity, as they reduce barriers of access due to lack of home internet, home **computers, and extended chunks of time. The reality is that for some students, their phone is "a lifeline to education" (Baldwin & Ching, 2020, p. 420). While mobile devices can be defin**ed broadly to include any portable device, such as a laptop, tablet, or phone (Colin et al., 2021), this study focuses on smartphones. Given the integration of digital materials in higher education (Elliott, 2022), students need to be able to use the internet to successfully access and complete course content regardless of the modality of their course. As such, this study focuses specifically on how students use smartphones for learning given integrated internet access.

Students may not have access to a computer or laptop. In some cases, students may also be sharing a laptop with family members. Huerta et al. (2021) noted in surveys and focus groups with racially minoritized community college student parents that in addition to struggles with home internet, student parents often shared a laptop with their children and did not have access to their own laptop for coursework. For many students, being able to use smartphones for learning is a matter of convenience that can be preferable to computers that are slow to load or even turn on, or that are shared by more than one person.

Not all students have access to extended periods of time to work on coursework. The majority of college students balance long commutes, family obligations, dependent care, or multiple jobs (Aslanian & Clinefelter, 2012; Nguyen & Kramer, 2023; Remenick, 2019). For student parents in particular, the multiple demands on their time can make completing coursework challenging. Huerta et al. (2021) note:

> In addition to managing their own coursework, they [student parents] support their children's homework, domestic responsibilities (e.g., meals, washing clothes, bathing children, unexpected illnesses and doctor's appointments, or lending support to extended families). These demands on their time limit studying to the late evening or before dawn, when they have time and space to concentrate on assignments and tests (p. 4).

For student parents, the stakes are high. According to Huerta et al. (2021), **"A single miscalculation can upend** their daily, weekly, or semester-**long goals and objectives" (p. 4)**. And yet, educational attainment can transform the lives of student parents and their children in long-lasting and profound ways (Nelson et al., 2013). As such, leveraging smartphones to provide students convenient access to learning anytime/anywhere provides a unique opportunity to increase access to high-quality educational opportunities and to reduce barriers that arise due to external demands on students' time.

While smartphones reduce access barriers, they are underutilized (if not banned altogether) in higher education contexts. And though students frequently use smartphones in their personal lives, they are less likely to use smartphones for learning (Kirschner & De Bruyckere, 2017)—and need guidance on how they can leverage the technology in their pockets to support learning. Also, cell phone policies that ban smartphone use in college classrooms continue to be implemented (Stachowski, 2020).

Research on smartphone usage in education typically focuses on the impacts of mobile learning on achievement and specific instructional examples of mobile learning (e.g., Crompton & Burke, 2018), as well as student access to technology (Elliot, 2022). In addition, COVID-19 prompted researchers to study how students use smartphones for online learning, specifically in regard to the amount of mobile device usage during an unprecedented period of ubiquitous remote learning (Edumadze et al., 2022; Vishnu et al., 2022).

While COVID-19 exposed students and their instructors alike to the experiences of engaging with remote learning, it is challenging to use data from the COVID-19 pandemic to reach broader conclusions about the possibilities of learning with smartphones given that many students had no other options but to access instructional materials from a smartphone. As such, there is a need for research that works to develop an understanding of how students use smartphones for learning across modalities; how students do not like to use smartphones; and the ways in which they would like to use smartphones for learning. This study addresses this need by examining the results from focus groups with students from a California community college, a California state university, and a University of California campus.

Methods

This study draws from student focus groups on the use of mobile technologies for learning across California higher education institutions. Our research specifically focused on student experiences when engaging with

mobile learning in their STEM courses as part of a larger California Learning Lab grant project, which helps improve student access to instructional materials that historically contribute to STEM pipelines. The focus groups were conducted at three campuses: a California community college (CCC), a California state university (CSU), and a University of California (UC) campus.

Principal Investigators (PIs), at each campus, recruited up to 10 participants per focus group session. All focus group sessions lasted up to 2 hours and were held over Zoom. Across all three campuses, a total of 22 students participated in the focus groups, which explored the following research questions (RQs):

- RQ1: How have students used smartphones for learning (e.g., accessing and engaging with coursework) in their prior STEM courses?

- RQ2: What are the limitations of—and student concerns with—using smartphones for learning, particularly in STEM courses?

- RQ3: What are the ways that students would like for their instructors to understand how they use or would like to use smartphones for learning?

PIs organized and led each focus group session at their campus using a semistructured interview format (Merriam, 2009). Interview questions were broken into three parts, according to the following categories: (1) mobile first; (2) calculus and STEM; and (3) inclusive courses (students) or open educational resources (OER) and instructional technology (instructors). For RQ3, students shared their inclusive learning experiences (see Appendix A).

Focus group sessions were recorded through Zoom for transcription and analysis. Recordings were later destroyed, and names were replaced on transcripts with pseudonyms to de-identify participants.

PIs utilized qualitative analysis focusing on first open coding to "springboard" ideas of other categories to include (Strauss, 1987, pg. 63) in the study. Then, PIs used axial coding to refine and eliminate codes—as well as to better understand relationships between codes. In collaboration, PIs iteratively reviewed and analyzed transcripts from their individual campuses to uncover themes, which were collectively aggregated and further refined. PIs then conducted a second round of analysis according to the newly refined themes. Corresponding excerpts were collected and shared according to the various themes.

Results

Focus groups with students show that: Across California public higher education institutions, students shared common uses of smartphones for learning. These common uses helped students complete coursework while on the go, as well as to make use of the in-between moments of their day. Students also found their smartphones were helpful to use as an emergency back-up when technology stopped working, or in the absence of reliable internet access. However, students expressed frustrations with the technical limitations of using smartphones for learning. Findings also indicate strong student preferences for hands-on practice in math and science courses.

Common Smartphone Uses for Learning

Students frequently used their phones to complete tasks on the go, make school more convenient, persist when challenges arose, and stay organized. In each of these cases, students found that their smartphones allowed them to make use of the small chunks of time in their day for coursework and to continue in their coursework despite issues with technology.

Smartphones Helped Students Complete Tasks On the Go

Students across the UC, CSU, and CCC frequently spoke about the benefits of using smartphones to complete coursework "on the go." The convenience and ease of accessing a smartphone were the primary reasons for using a smartphone to complete coursework.

- Students used smartphones to make use of time in transit. By completing tasks on the go, students were able to take advantage of time in transit. As Luis, CSU, noted:

  > I'll have like a lot of my assignments that will pile up … So, I will do like the ones that are new, like Word documents and such, on my computer. And then the ones that I may be able to do on my phone, I will save them, so I can do them on my way to school, the next day, especially as I use public transport to get there.

  Luis was able to strategically work on assignments that were not mobile-friendly when he had access to his computer. Then he could make use of his commute time on assignments that he could use a phone to complete.

  Delores, UC, also observed her friend using her phone to make use of commute time for schoolwork. As she said:

  > I have a friend who travels … but they're far away from their school, and they can't dorm. And so, they have to do a lot of traveling by train. And they don't want to have the hassle of taking out their laptop … So, they use their mobile phone to do their coursework.

  Since Delores's friend was not able to live on campus, they were able to make use of their train commute to complete coursework on the go. Using a smartphone proved more convenient to work on while in transit.

  Students also relied on a phone to stay up to date **while walking. As Dolores said, "W**hen I'm on **campus walking to my classes, I will use my phone to review any updates that come across." Dolores** found it helpful to be able to use her phone to stay up to date while walking.

  At the CCC, students noted the benefit of using a smartphone to access Zoom while driving. In fact, during the focus group, several students were accessing the Zoom meeting from their phones while **driving. Sadie said, "I don'**t have internet on my computer or on my iPad, except in school or home (where I have Wi-Fi). That's why right now I'm … driving and I'm using my phone to do the Zoom **meeting."**

  For Sadie, she appreciated being able to access Zoom on her phone when in transit, as she did not have internet on her iPad or computer except at school or at home.

- Students used smartphones to complete coursework anytime/anywhere. Students also found that they were able to use smartphones for learning, as they always had their phones with them. As Salman, CSU, said:

  > So, the reason why I would use my phone is because I always have it on me. It is easily accessible, [and] I won't have to worry about having a laptop or a computer or my iPad on me. So, if there was a way that it could be simple and easy to use, I would prefer to use my phone. Because that would be on-the-go, and I use my phone for almost everything else, so it would be very natural for me to just use my phone.

Since Salman already has his phone with him and uses it for "everything else," he has found that it is easy to use when he is on the go.

Isabela, UC, said, "**If you**'re on the go, it makes it really easy to be able to pull your notes and just like **do quick studying before class.**" She found it was easy to use her phone to study before class, and this ease of use was certainly a benefit that supported learning on the go.

Constant access to a smartphone helped students to record thoughts or ideas for assignments anytime and anywhere. Pepa, UC, notes, "**I really don**'t use my phone unless it's writing a paper and I'm just thinking like, yeah, and I'll quickly write i**t in the notes section to just refer back to it later.**" While Pepa did not often use her phone for learning, the benefit of always having her phone meant she was able to use it to record her thoughts or inspiration when away from a computer.

Being able to complete coursework on the go, however, was not always a positive experience. Samuel, **CCC, said, "I was in the McDonald**'s drive thru and my assignment was due soon. I had to turn it in at night. I wouldn'**t ever do that again, but it does work.**" While turn**ing in his assignment in the McDonald's drive thru wasn't a positive experience, using a phone to submit an assignment did allow Samuel to still meet the due date.

By using smartphones, students were able to make use of commute times. In this way, smartphones were an important tool to equitize learning for students who could not live on campus or who did not have access to Wi-Fi outside of the campus or at home. For students, using their phones to complete tasks on the go helped to make use of time in transit, record ideas while out and about, and study while on the go. In this way, students were able to use their phones to complete coursework anytime and anywhere in ways that supported learning and helped make use of all moments of the day.

Smartphones Helped Students Make School More Convenient

Students also found that smartphones made school more convenient by allowing them to review, submit assignments, and watch lecture videos at times that worked best for them. For some students, this encouraged them to review more frequently and to make use of time that would otherwise not be used for schoolwork (e.g., while cooking dinner or showering).

- **Students used smartphones to complete assignments.** Students also noted that smartphones helped to make some assignments easier to complete, especially when devices could be used to submit an assignment directly to Canvas.

  Luisa, UC, had recently discovered that she could use her phone to submit an assignment directly by recording herself. She said:

  > I mainly use my laptop or my iPad for completing coursework. It's actually only this quarter I started using my phone and that's actually just submitting audio files. So, like on your phone, if you have the memos app and you record yourself, and then you submit that recording directly to Canvas. That's the only time I actually do coursework on my phone. If I have office hours with the professor, I use the Notes app—things like that. But besides that, I just mainly use my laptop.

  While Luisa predominantly relied on her laptop, she did find that when she could easily submit an assignment from her phone, she made use of this convenience.

  Just as Luisa mentioned the Notes app, students found that this was a convenient way to submit **assignments. Sasha, CSU, noted, "I would u**se the Notes app on my iPhone to like take a picture and

save as a PDF and then **… submit it to Canvas." Being able to submit an assignment directly to the** learning management system provided an opportunity for students to leverage their smartphones to make assignment completion more convenient.

- **Students used smartphones to review course content.** Smartphones helped make reviewing **coursework easier and more convenient. As Fatima, CCC, noted, "I use the app Quizlet to make** flashcards, like virtual flashcards, so whenever I'm on the go or playing with my phone. I'll take a **break and study my flashcards." In this case, Fatima found that using flashcards on her phone made** reviewing more convenient and she was able to do it when she was on the go or playing with her phone.

  Students also found that their phones helped make it convenient to watch video lectures. Sarah, CCC, said:

  > And so, I literally, you know, I'm taking a shower and I'll have it [my phone] over on the shelf and I'll be showering, and I can like watch the math video. Or I'll be, you know, cooking dinner or something, and I can just like hear it, and just like keep hearing it.

  For Sarah, being able to watch lecture videos on her phone helped her make use of time while eating lunch or throughout her day. This was important for her as she was a returning student with three children. Making use of this time in the day was essential for her to make progress toward her degree.

  Pepa, UC, found that she could use her phone to not only watch video lectures but also to complete **quizzes when embedded in the lecture. As Pepa said, "Sometimes I will use my phone to watch video** lectures that the professor posts, if they're just really quick, and they're like multiple choice quizzes embedded within the lecture videos. I**'ll do that." In this case, we can see that when there was an** embedded quiz, the student was not only able to watch the lecture video but interact more deeply with the content.

Students used their phones to review, submit assignments, and watch lectures for courses. In some cases, this accessibility helped students review and watch lectures more often than they would have done without their smartphones. Students who were balancing childcare and outside responsibilities were able to leverage their smartphones for review, submissions, and watching lectures to make strategic use of small chunks of time in their day.

Smartphones Helped Students Persist When Challenges Arose

Perhaps one of the most common uses of smartphones was to persist when the internet went out or when a computer died. As Salman, CSU, noted:

> I usually have pretty good access to Wi-Fi, especially on campus and my apartment. Only a couple times in my apartment the internet [would] go out and I [would] just use my phone as a hotspot. I just want to say I love unlimited data, and that is a great convenience.

Salman usually had access to reliable Wi-Fi, but he did find his phone helped when the internet went out at his apartment. In this case, his phone served as a convenient back-up.

Luisa, UC, also found her phone to be useful when there was an internet outage. She said:

> I really only use my phone if there's like an internet outage and that's like if my internet cuts out and I'm in the middle Zoom class, then I use my phone to hop on Zoom. Because … I actually just download the materials, so I'm not dependent on Wi-Fi at that point.

Luisa used her phone as an emergency backup to access a Zoom class if the internet went out. She also made sure she had materials downloaded so as not to have to rely on Wi-Fi.

For some students, access to internet varied depending on where they lived. Pepa, UC, said:

> I think, for me, because I live on campus at North District, and we've had a couple of internet issues. Sometimes I have to refer to my phone. I would prefer not to, but sometimes it forces me to refer to my phone to look up the textbook or the resources on campus just because the internet might be out. I don't know if other people have that problem, as well, but in the North District [it] happens quite often.

For Pepa, she often experienced internet outages, because of where she lived. Even though she would have preferred not to have to use her phone, she did rely on it during frequent internet outages.

Isabela, UC, used her phone when her laptop died. She said, "If I need to write [a] paper in between classes and ... my laptop is dying or something, I'll [use my phone]. But generally, I will aim to try to do most of my work on my laptop." While Isabela did not like writing papers on her phone, she did find that she had to use it occasionally to continue working on a paper when her laptop was dying.

Though students expressed a preference for using a laptop to write papers or attend Zoom classes, they did note situations in which they relied on their phone due to internet outages or computer malfunctions. In these cases, students either used their phone as a hotspot, or they used their phone to continue working on coursework. In these situations, smartphones provided an emergency bridge in which students could continue working on their courses despite disruptions to internet.

When students use their phones as a hotspot, they will continue to experience a course on a computer but may find pages load more slowly, or they are not able to stream videos as quickly. However, students who use their phones to directly access a course, when the internet goes out, may face difficulty accessing a course that is not designed to be experienced on a small screen. In each of these cases, students rely on their phones to persist despite disruptions, but their experience may vary.

Smartphones Helped Students Stay Organized

Smartphones also helped students stay organized. Samuel, CCC, said this about accessing his coursework on his smartphone, "It's good because it allows me to see all this stuff due." Samuel appreciated being able to see everything that was due in his class.

Fatima, CCC, also found that her phone allowed her to get a sense of everything she needed to do. She said, "I could review ... basically the overview of what's coming up and what's gonna happen, like in today's class." In her case, her phone helped her to see an overview and get a broader sense of what was coming up next in her course.

Sarah, CCC, used her phone to keep track of her to-do list. As the CCC in this study uses Canvas, she found that she used the to-do list on the Canvas app. She said, "I do use it as like my to-do list. I like the way that the to-do list populates on my phone." Sarah found the to-do list was easy to use and access on her phone.

In each of these cases, students were able to stay organized and gain a sense of what was coming up and what they needed to do for each of their courses. This quick overview of their to-dos and upcoming events helped them stay organized and helped to support progress on their coursework.

Smartphones Helped Students Communicate and Connect

Smartphones also provided an opportunity for students to communicate and connect with other students in their courses. Jessica from a CSU said:

> One thing that I have found very beneficial this semester—having my phone with me—is the app Discord because we are in, like a little program together. We all have the same classes. We all communicate about concepts that people don't understand and … like we can make a study group through the Discord and a lot of people when we're doing homework and there are questions that are very difficult. We just send them in [on] **Discord and people say, "Oh, I found this information on like page 300 something," …** It's really useful, because you're able to get other perspectives, and they send tools (like videos) that they find as well, which can help you be more successful in the course.

Using the Discord app on her phone helped Jessica to connect with her peers and form an asynchronous and mobile study group that ultimately supported her success in the course.

Limitations of Smartphones for Learning

Despite the "various use" cases that students named for using smartphones for learning, we observed that there was an almost equal amount of discussion about the significant limitations of using a smartphone for learning. Across the three focus groups, we noticed that the limitations students cited primarily focused on the technical constraints of using a smartphone for learning, specifically in terms of concerns with a smartphone's size and physical comfort for doing schoolwork and with a smartphone's functionality for running educational applications.

Students Experienced Hardware Limitations

Many students expressed a concern that using a smartphone put them and their peers at a disadvantage for completing their schoolwork, especially when it came to assignments like writing, entering formulas, or taking graded quizzes and exams. Laptops, by comparison, were viewed as the more favorable device for completing coursework. Isabela, UC, said: "Generally, I do most of my work on my laptop. Generally, from my phone, it'll just be for reviewing notes and that kind of thing. Not really like doing actual work."

The size of a laptop screen and the ability to open multiple applications and view them at once made a laptop more desirable for schoolwork than a smartphone. Sadie, at the CCC, expressed how she avoids using her phone for schoolwork because, she says, "I don't prefer … smaller things. I think [the smaller screen] does not help me in my education." At CSU, Luis similarly cites problems with the small screen. "The material is too small for me to see … Especially when it's on Canvas [LMS]," Luis shares. "There's a lot of times where it doesn't load, and I have to keep reloading … Then I have to go back and look for it."

Concerns over the small screen size reflect preferences for using a larger device in addition to the limitations in overall functionality negatively impacting the ability to complete schoolwork in a timely and efficient way. Given that instructors post instructional materials online too, the challenges with academic workflows on a smartphone may be especially exacerbated. At UC, Isabela explains how accessing lots of different pieces of information on a phone is difficult:

> It is hard to do worksheets on your phone … [I] need to be able to use a calculator or look at the textbook, as well as looking at the questions, all at once. So, unless I have either a physical copy or like my laptop—like another screen—to be able to do that, it is a lot harder because … you just need a lot of tabs open.

The interest in having a "physical copy" of a textbook or a worksheet was reflective across all three focus groups insofar as students expressed frequent preferences for engaging with equations or formulas on paper rather than on screen. This observation suggests that instructors primarily distribute course materials and practice problems in texts and worksheets that are designed primarily for paper rather than for the screen itself.

Students Experienced Software and Application Limitations

Across the three focus groups, the limitations of using particular assigned platforms, tools, or applications from different classes emerged as a predominant concern about the technical limitations of using a smartphone for learning. At **UC, Dolores spoke about how "you can'**t access as many platforms on the phone **like you can with your computer."**

Pepa, also at UC, expressed a preference for using her laptop over her phone due to a lack of storage on her phone. **"A lot of my professors pos**t worksheets for me to do so I can't really just download it on my phone**,"** she said. "My phone doesn**'t have enough space for that if I have to continue doing it." Pepa found her** professors were not necessarily considering the limitations to storage and working memory of accessing large files, like PDFs, on a smartphone.

Even for students in classes with faculty who were actively adopting online applications for their learning, many students spoke to the challenges of using those applications specifically on smartphones instead of computers. Many students spoke about the challenges in using Zoom, a popular synchronous web conferencing tool, through the mobile application. Sarah, at the CCC, spoke specifically to how hard it is for students to share their screens if they're using Zoom from a smartphone**. She said, "**I feel for them because all they have is a little phone … I know that's difficult but they're using it because it**'s the only thing they have." The smartphone was clearly perceived as a less preferable "last resort" or a "second choice," particularly for** online learning.

Specific math applications were also cited as a cause for frustration when used on smartphones. Ethan, at CSU, gave the example of using a platform called WebAssign, which, **he said, "is really not accessible on** phones … you need a laptop or a PC in order to do that." Ju**lia, also at a CSU, gave another example of a popular math homework assignment learning management system application, called Pearson MyLab and told a story of trying to use MyLab from her phone:

> There was a time when I couldn't use my computer or iPad … I was in statistics, and it was not working on my phone … [I]t was so frustrating, and I ended up probably not doing the assignment honestly. I even had the app, but I had to try to download Google Chrome on my phone and even then, it just didn't work on my phone … When I was doing Pearson [MyLab], it would actually mark a lot of answers that I answered correctly incorrect because I didn't put a zero before the decimal and it would mark it as incorrect. I would have to go over and redo the assignment, or I have to just accept the loss on the points.

The frustration, anxiety, and concern with missing a homework assignment—or being unable to complete work because of a technical glitch or difficulty—drove many of the student respondents to their preference for using a laptop over using a smartphone, especially for particular math assignments.

Potential Uses of Smartphones for Learning

Among students who were interviewed as part of our study, there was a majority consensus that learning on a smartphone is harder than learning on a desktop or laptop computer, but almost as many agree that the availability and use of a smartphone is crucial as an emergency bridge in the absence of reliable internet. In

addition to having reported challenges to completion of coursework resulting from problems with connectivity, students also expressed having faced learning challenges relating to content mastery and the learning environment itself. In response to the question about which strategies help students to succeed in STEM courses, Isabela, UC, answered decisively:

> Definitely practice problems and then specifically ... working through problems with a TA ... step-by-step, so ... I know exactly where I'm doing something wrong. Just like ... definitely being [able to] go through each process in the problem and actually being able to understand that this is exactly what I got wrong—this is what I need to work on in the future ... I feel like that ... definitely helped me a lot.

Students also expressed a need for understanding the application of concepts to real-world contexts. Luisa, **UC, indicated, "when that**'s not there ... it's very much like learn it, regurgitate it. Like there's no reason behind why you would use the math in the first place," **describing instructors who were able to situate** learning in real-**world contexts as "grounded," with capabilities to "(make) the material so much more accessible" and "relatable." She described the opportunity for practice as having "completed the** 'learners learning circle' for me. It was like, okay, theory, application, and then, now **'do it... for me.'** That's how I **learned a lot in that class, and I really enjoyed it."**

Interestingly, students differed in opinions about whether the opportunity for practice should carry credit. Pepa, UC, suggested:

> No stakes is ... good because I think that's "stress" whenever a student hears "quiz," "test," "midterm." Automatically their brain kind of seizes up ... So to get the highest grade they possibly can ... to learn well, to learn proper, and actually retain that information, having quizzes is fine as long as there's no stakes involved.

Luisa, UC, disagreed, arguing:

> When there's no stakes involved ... there is less pressure on the student, so they tend to sometimes do better. But on the flip side ... when there's the stakes involved, there is that pressure like I need to actually try... . The practice problems around that material incentivize students to do well because there's like a point system or something along those lines, if there's some sort of way to ... intrinsically motivate the students ... I'm not really sure how to exactly do that, but if there's some kind of way to do that, I think that would help a lot.

A natural reason for students to want to engage with content through the opportunity for practice is the **interest and capability to receive feedback. Sarah, CCC, noted: "I love to have that feedback. Like immediately. As fast as possible." Students across institutions noted the desire for detailed and immediate fee**dback as well. Megan, at a CSU, for example, proposed that a helpful application for a smartphone would simply be something that would give students access to a bank of practice problems:

> I learn better through practice and repetition, and so when I took calculus 1, 2, and 3, I bought workbooks separately on my own, too, because the way I [learn] is by repetition and doing it—and like, seeing a problem six different ways.

Dario, also at a CSU, built on Megan's ideas by suggesting an interest in a mobile app **that could "dynamically generate problems" so students could get lots of opportunities** for practice with immediate feedback.

Beyond hands-on practice or application and access to more detailed, more immediate feedback, relationships clearly impact the degree of satisfaction and perceived quality of learning opportunities. Students obviously value the opportunity to receive direct instruction or feedback from their instructors, teaching assistants, and **peers. Isabela, UC, volunteered her strategy, that "whenever the professor would ask a question during class to**

just shoot out an answer sometimes to see (if) you know because ... it helps ... to get that practice in, to review the material, **and then ingrain it."**

Students at a CSU cited the benefit of study groups and sharing notes with friends in their classes. Amelia at a CSU noted that a combination of study groups, tutoring groups, and instructor office hours were the most important strategies that helped her succeed—underscoring the importance of getting feedback from her **peers. Dario also said that study groups were "number one" because "being able to work together—**either with people in your class or people in different sections—to work through the problems ... saved me many, many **times."**

Students also expressed appreciation for access to review materials, including lecture materials or recordings. Delores, UC, lamented that fewer instructors were posting course content online with the return to in-person instruction, stating:

> In the beginning ... our math class ... was online, and it was really nice to have all of the lecture recordings accessible online. Now that we're back in person, there's not as much recording ... It was nicer to have the recordings that you can get to. I think that was very helpful.

Isabela, UC, echoed this sentiment, stating:

> I took [a course] at the beginning of the pandemic. So, everything was very much online. I like that aspect because everything felt very accessible ... in terms of all the information. Like, if I couldn't find something in the textbook, like, I was able to search it up on my own, or if I really needed to, reach out to a TA in office hours.

Some students went outside of their instructor's official instructional materials, turning to places like Khan Academy or YouTube for added support. Beatric**e at a CSU, for example, called YouTube her "best friend" and** Jessica, also at a CSU, similarly noted that even her professors would encourage her and her classmates to **take advantage of living in the "technology age." Jessica explained**, "All of my profess**ors say, like, you have** this tool, you should use it. If you don't understand a concept, they'll give us tools like YouTube videos that'll **help explain it." Curiously, there seemed to be no connection between using a smartphone to access these** materials even though resources like YouTube videos could be accessed just as easily on a smartphone as on a laptop computer.

Students spoke with overall conviction about the various strategies that were helpful in supporting their achievement in STEM courses. Isabela, UC, thoughtfully observed, **"I think there are certain qualities to** courses that ... **consistently make me excited about each of them," which also suggests that instructors can** enhance student learning experiences through thoughtful and deliberate course design. The emergence of common themes bodes well for instructor capabilities to leverage mobile learning to address student learning challenges and to accommodate student learning styles, strategies, or preferences.

Students unmistakably value relationships, which are proven to support student success and retention. Personal digital devices can provide increased access to materials and course content online just as easily as they can be used to support communication and personal connections, to address the challenge of students feeling lost, alone, or disconnected.

Discussion

Focus groups, consisting of students from a CCC, CSU, and UC, offer insight into what ways students use smartphones for learning; what ways students avoid using smartphones for learning; and student needs for

STEM courses. The findings from these focus groups have important implications for educators and designers, as they design courses that leverage the largely untapped potential of smartphones for learning.

Phones, Persistence, and Barriers to Access

Students at a CCC, UC, and CSU used their phones to:

- Complete tasks on the go.
- Make school more convenient.
- Persist when challenges arose.
- Connect with peers.

In each of these examples, students use smartphones to realize the unique affordances of smartphones for learning, such as anytime/anywhere learning (Ally, 2013; Barden & Bygroves, 2018), convenience (Barden & Bygroves, 2018), and connection (Cochrane & Bateman, 2010; Cross, 2019; Danish & Hmelo-Silver, 2020; Nasser, 2014). Students also found their phones helped them to fit coursework into their busy schedules, stay organized, and access courses despite internet outages. In each of these examples, smartphones helped students to make progress in their coursework in ways that fit into their lives.

Students across institutions found that they were able to make use of commute times and times in transit by using their phones to complete tasks on the go. Whether students were riding a train or walking to class, they noted using their phones to make progress on assignments. This is an important benefit of smartphones to consider, particularly in light of the multiple demands on their time students across higher education institutions are balancing. The so-**called "traditional" student who lives on campus and does not work outside** of attending classes is no longer a norm—even at residential 4-year institutions (Aslanian & Clinefelter, 2012; Nguyen & Kramer, 2023; Remenick, 2019). In our focus groups, we found that students used their smartphones to make use of commute times for learning whether they were at a resident 4-year institution like a UC or a community college.

As students always had their smartphones with them, they were able to make use of their phones to complete tasks on the go. This helped to expand learning beyond the classroom and realized an affordance of smartphones to support anytime/anywhere learning (Ally, 2013; Barden & Bygroves, 2018). As Pepa, UC, **noted, "I really don**'t use my phone unless it's writing a paper and I'm just thinking like, yeah, and I'll quickly write it in the notes section to just refer back to it later." Having constant access to a smartphone facilitated anytime/anywhere learning and helped extend learning beyond the classroom.

Students also used their smartphones to make learning convenient. Across all three focus groups, students noted that they were able to leverage their phones to make use of times that worked for them to review, submit assignments, and watch lecture videos. Smartphones hold a tremendous potential for equitizing higher education by facilitating opportunities for students juggling childcare, elder care, family responsibilities, multiple jobs, and long commutes to take advantage of the in-between moments of their day for learning. Students also indicated that they reviewed more because their phones made review more convenient, whether it involved rewatching lecture videos or reviewing note cards via a mobile app.

Smartphones were also an important tool to help students persist despite potential interruptions to learning caused by unstable internet or unreliable technologies. As students view smartphones as an emergency tool that they can use to persist in courses despite external hurdles, there is a potential for educators to make use of smartphones more deliberately to support students in normal times and during disruptions in education. Even before the COVID-19 pandemic, the frequency of disruptions to education posed challenges as climate change worsened extreme weather events, such as floods and wildfires.

Students also shared that their smartphones helped them stay organized and have a larger sense of what was due. This is an interesting finding that contradicts a commonly cited limitation of smartphones for learning: The small screen (Eschenbrenner & Nah, 2019). While the small screen of smartphones is often cited as a limitation for learning (Eschenbrenner & Nah, 2019), when an app like Canvas is effectively designed for smartphones, the limitation of the small screen can be overcome.

Finally, while students did not frequently note using their phones to connect with other students, Jessica at a CSU recounted how she was able to use Discord to get feedback from her peers on difficult course concepts. One benefit of smartphones for learning is the potential to support connection (Cochrane & Bateman, 2010; Cross, 2019; Danish & Hmelo-Silver, 2020; Nasser, 2014). This finding illustrates the potential of smartphones to be used for connection in higher education. It also highlights the power of creating opportunities for students to engage with smartphones for learning in ways that approximate what they are accustomed to using smartphones for in their personal lives. In other words, if a student already uses their smartphone for connection, it may be more likely they will use their phone for connection within a course when the opportunity is created for them to do so.

Negative and Instrumentalist Perceptions of Phones for Schoolwork

The students across all three focus groups generally agreed that they thought of phones primarily as supplements to schoolwork, not replacements for primary devices for completing schoolwork. Even students who once relied upon a phone for schoolwork found that if they had access to a laptop or a tablet, like an iPad, for learning, they preferred the larger devices. At a CCC, Sadie explained, "I didn't know [using a smartphone] was a bad experience until I bought my computer and iPad to compare it to." The idea that smartphones were an inferior device to laptops or tablets for learning was a clear theme, even though students across all three focus groups mentioned that they owned smartphones and brought them more frequently to classes than their laptops or tablets.

Even though smartphones are tools designed largely for communication, many students did not see their phones as a tool explicitly to communicate with other students or their professors. Rarely were the primary functionalities of a smartphone mentioned in the context of supporting student learning. Instead, students perceived their phone primarily as a place to access content uploaded by their professors online. Given the experience of a phone—primarily as a container to convey and download information—the smartphone tended to be viewed in a technologically instrumentalist way; that is, the technology was a vehicle for the students to receive information. Given this orientation, most students did not necessarily think that a phone would "harm" their learning, even if it was frustrating and limited to use.

Some students noted that a phone could be perceived negatively by their instructors even if it was not necessarily harming their learning process itself. Sarah, at a CSU, for example, explained how "if I got on my phone ... the professor might think I'm scrolling down social media or whatever." At CCC, Sadie explained how the phone could be a distraction from coursework because. "When you use your phone," she said, "you can see messages from social media, from your family, friends." And while none of the students across the three focus groups spoke to or explained concerns with receiving these messages during class, the implication was that social messages did not have a place in classroom instruction, and many students explained that smartphones were always "distracting" for learning. In fact, socializing itself—outside of the context of a study group—was not a core way to engage with learning that students cited or expressed.

The smartphone, broadly speaking, was not cited as something that instructors thought about or addressed explicitly in their classrooms, unless it was in a punitive context. Megan at a CSU expressed how a lot of her professors do not recognize the value in using a phone for schoolwork:

> I think a lot of it is just having professors that have the mindset that we don't need to use the internet because you have the book … I think it's maybe also a cultural shift in our thinking of the way that we can take different types of information as being useful and whatnot.

The dichotomy between "the internet" and "a book" suggests that neither students nor their instructors recognized the accessibility of text**books being available on "the internet**." And, in fact, "the internet" was perceived as a place only where "book" materials could be downloaded, not where learning itself could be discovered or explored.

Instructors and designers might consider how concerns with smartphone usage could be explicitly addressed when designing a curriculum. Specifically, instructors and designers might provide explicit instruction to students about when, how, and why using a smartphone might be useful at specific moments in the curriculum. If there are units within a class that could be accessed via a smartphone, an instructor or designer could label that component specifically to help students understand whether using a smartphone could work for them.

Instructors and designers may also want to be mindful of the materials they use, the applications they adopt, and whether those materials or applications are accessible on a smartphone. The responses from these focus groups suggest that instructors and designers are likely not testing smartphones extensively when choosing which materials to adopt. Instructors and designers may especially want to view how their instructional materials appear when accessed through the mobile application for the learning management system (LMS), knowing that students may be attempting to view information through the mobile app when accessing their coursework.

Importantly, there are tremendous cultural barriers in higher education when it comes to smartphone adoption for academic use cases. For students, smartphones are simply not perceived as academic devices. This is likely because of lack of exposure—both for students and instructors—about the wide range of ways that smartphones could be used for learning.

Instructors may be key stakeholders in need of professional development around the possibilities for using smartphones in more creative ways in the classroom. While a good starting point for instructors may be simply to ensure that instructional materials can be accessed on a smartphone, centers for teaching and learning, IT divisions, and other campus units that support teaching and learning may aim to consider what other kinds of pedagogical possibilities are available to students who may need to use a smartphone, or who wish to use a smartphone more extensively for their learning.

Conclusion

Smartphone ownership among college students is nearly ubiquitous, yet students' experiences with using smartphones for authentic and meaningful learning remain relatively rare. Intentional engagement with technologies of all kinds, in the classroom, needs to be cultivated at the level of faculty development so that students can understand and appreciate all the possibilities for engaging with the tools and technologies that are part of their learning experiences. From our focus group research, it is clear that students are rarely exposed to classroom pedagogies and practices where technologies are used for more than content delivery and the completion of individual homework assignments. These use cases may be valuable to student learning, but it is clear that higher education faculty may benefit from more exposure to the possibilities of using smartphones for teaching so that students have a clearer understanding of the options and opportunities available for their learning. Smartphones also have the potential to help students develop constructive tendencies with the use of personal digital devices that support the development and application

of 21st-century digital skill sets, like collaboration, communication, creativity, and critical thinking to **authentic, "real-world" problems or contexts.**

We know learning is social, and that one of the most common use cases for a smartphone is for communication. Future research might more specifically explore how students form social connections with their classmates or professors through asynchronous social connections on their smartphones. We recognize that this is a challenging research area to explore given the potential concerns with student privacy and accessibility when using social media applications for educational purposes. However, it may be worthwhile for educators to understand what some of the options are for fostering student engagement and connection on a smartphone to consider what the development of more socially engaged educational applications might look like moving forward.

For math education, in particular, students spoke most consistently about the value of practice and the opportunity to work with a variety of math problems. Future research might explore how mobile applications could be improved to foster greater engagement with practice problems while also exploring ways to overcome the significant technical limitations of using educational applications for mathematics education. Until online interfaces and mobile applications are designed with mathematical cases in mind, the opportunities for students to engage in math problem-solving may be quite limited.

Prior research demonstrates that the most historically marginalized students are the same students who are most likely to rely upon a smartphone for learning. Determining better ways to galvanize smartphones for learning so all students can have equal access to valuable learning experiences—regardless of their access to particular devices and technologies—will contribute to closing one of higher education's many equity gaps.

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Appendix: Student Focus Group Semistructured Script

Thank you all for being here today! We are excited for the opportunity to better understand what makes a successful calculus course that can be completed entirely on your phone. Today's focus group will help to inform the design of a mobile-friendly online calculus course shell that will be made free and widely available on Canvas Commons in December 2022. We are working with a team that represents math faculty and instructional designers across California community colleges, CSUs, and UCs.

First, let me introduce myself. My name is ... [facilitator introduction].

Before we get started, I would like to remind everyone that this session will be recorded. This recording will not be shared with anyone outside this project. Any publications or conference presentations will use pseudonyms in place of participant names. If you don't want to answer a question, you absolutely do not have to. We are looking to have a conversation that will help inform the design of the calculus course shell.

Now I'd love to have you all introduce yourselves. Please tell me your name, what your major is, and what your career goals are.

Questions:

Mobile-First
1. Do you use your phone to complete coursework? If so, how? How frequently?
2. How have your courses allowed or prevented you from using your phone to complete your coursework?
3. Why do you or other students you know use their phones to complete coursework?
4. To what extent does lack of internet at home drive you to use your phone for coursework?
5. How does using a phone impact your learning? Does being on a phone make it easier for you to learn? Harder? Not much impact?

Calculus and STEM
1. What are the most important aspects of a calculus course shell that can be completed entirely online?
2. What strategies have you used in STEM courses that help you succeed?
3. What are some difficulties you have encountered in STEM or math courses?
4. What kinds of learning activities best help you learn in STEM courses (video with embedded quizzes, group work, practice problems, individualized feedback ....)?

Inclusive Courses
1. Tell us about a course that made you feel intimidated or nervous.
2. Tell us about a course that made you feel welcome and excited.
3. What are some ways an instructor can help you succeed in a course?