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Content and Connections: Students' Responses to a Hybrid Emporium Instructional Model in Developmental Mathematics

A CAPR Working Paper

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Abstract

Innovation in instructional technology has contributed to the rapid implementation of technology-driven instructional platforms, particularly in developmental math coursework. Prior research has shown that instructional environment and classroom experience influence student development and outcomes. Consequently, when courses transition to technology-driven instruction, a logical concern on the part of faculty and administrators is the effect on the quality of the academic experience among students. Under a hybrid emporium model, students primarily receive instruction from a computer-based platform rather than from a faculty member delivering content in front of the classroom. This paper examines how students experience a newly adopted, hybrid emporium model for developmental math coursework. We conducted focus groups with students at six public colleges in Tennessee and find that students enrolled in hybrid emporium developmental math courses reported that the instructional model contributes to lowered barriers to math by increasing cognitive and social accessibility. In spite of prior academic challenges, students perceived math content and their faculty to be more accessible in the computer-driven model than in traditional lecture classes. We discuss these findings in light of recent research suggesting technology-driven instruction does not improve math performance.

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1. Introduction

Roughly half of all first-year college students arrive on campus underprepared for postsecondary academic work (Chen, 2016; Center for Community College Student Engagement, 2016). Most institutions offer additional coursework for these students, referred to as developmental, remedial, college preparation, learning support, or skills courses. These developmental courses are often the first academic environments that many students encounter in college. Unfortunately, enrollment in traditional developmental courses does not guarantee academic success. Students who enroll in remedial courses to improve their math, reading, or writing skills remain at risk for dropout and disengagement from college. Despite evidence of some positive academic outcomes for students who enroll in such courses (Bahr, 2008; Boatman & Long, 2018), other evidence suggests that remediation presents obstacles to the pursuit of credit-bearing coursework or contributes to the phenomenon of community college "cool out" in which students lower their academic aspirations (Bailey et al., 2016; Bailey, Jeong, & Cho, 2010; Deil-Amen & Rosenbaum, 2002; Edgecombe, 2011; Jaggars & Bickerstaff, 2018).

In response to students struggling through traditional developmental courses, institutions and, in some cases, state systems have crafted new approaches to remediation, many of which harness technology to guide students through competency-based learning modules (Arum & Roksa, 2011; Fay, 2017; Herreid & Schiller, 2013; Lage, Platt, & Treglia, 2000). The use of technology in online and in-class postsecondary instruction has grown rapidly over time, particularly in the remediation of mathematics skills (Allen & Seaman, 2007, 2010; Means, Bakia, & Murphy, 2014). Technology can be used to expand, strengthen, and create efficiencies in the delivery of developmental math courses (Epper & Baker, 2009). For example, technology-focused reforms can either accelerate students through their developmental course sequence faster by compressing the material into fewer semesters or they can allow students to move through the developmental material at their own pace, both of which have the potential to positively impact students' experiences and academic outcomes (Fong & Visher, 2013).

One popular strategy for incorporating technology into remedial mathematics courses is known as the hybrid emporium model, which eliminates lecture, uses interactive software, and provides personalized, on-demand assistance for students. At the beginning of the course, students complete a diagnostic assessment that identifies their math strengths and weaknesses. Students then spend much of their class time in a computer lab learning the course content online at their own pace, with faculty serving more as tutors who deliver individualized instruction rather than as lecturers. Faculty track student progress online and answer questions individually, both online and in the lab. The course content is divided into small blocks, or modules, and is taught using tutorials, practice exercises, and quizzes and tests. When students fail to master a concept, they are allowed to complete the module again, with new problems replacing the old. When students complete the number of modules assigned during the diagnostic assessment, they have passed the developmental math course and may typically move on to their gateway college-level math course.

Instructional redesigns generally may yield both benefits and challenges for students. Technology-driven redesigns may offer individualization of instruction but may lower academic engagement with faculty due to the nature and quality of faculty-student engagement and content delivery. This study seeks to illuminate students' perceptions of the benefits and challenges of learning developmental math under a technology-driven instructional approach. Using qualitative data from student focus groups at six public colleges in Tennessee, we analyze students' reactions to the hybrid emporium model. We address the primary research question: *What do students report as the impacts of developmental math instruction through the hybrid emporium model on their academic and psychosocial experiences in college courses?* While other research (see Boatman, 2019) estimates the academic effects of using the hybrid emporium model, in this paper we explore the student experience in a technology-driven classroom and consider how it shapes students' academic experiences more broadly. With the rapid adoption of the hybrid emporium model across college campuses, student voices, particularly those of individuals in need of developmental coursework, are underrepresented in the literature examining instructional changes. Our use of student focus groups brings to light the educational experiences of academically at-risk students who are taught using this increasingly popular instructional model.

We find that students enrolled in hybrid emporium developmental math courses reported that their classroom experience breaks down barriers to math learning through greater cognitive and social accessibility. In spite of prior academic challenges, these students perceived math content and their faculty to be more accessible in a hybrid emporium course than in traditional lecture courses. Their comments focused on access to academic content and a more supportive faculty-student relationship. However, despite the cognitive and social benefits students perceived after participating in a hybrid emporium course, recent research suggests that the academic outcomes for students enrolled in these courses are not necessarily improved (Boatman, 2019; Kozakowski, 2019). We conclude by discussing this tension and its potential impact on students' subsequent academic success.

2. Background: Technology-Driven Instruction in Developmental Math

Math curricula in the United States have increased in their cognitive demand over the past 100 years (Blair, Gamson, Thorne, & Baker, 2005). Whereas basic arithmetic comprised the bulk of the mathematics curriculum prior to the 20th century, demands for improved mathematics and science education at the beginning of the Cold War and into the 1990s have yielded more complex mathematics standards and greater requirements in compulsory and postsecondary education. This increase in mandatory math course-taking has not been mirrored in the evolution of other academic subjects.

It is not surprising, therefore, that 37 percent of U.S. teenagers report that math is their most difficult subject (Saad, 2005) and that students are more likely to fail developmental math than any other course in higher education (Le, Rogers, & Santos, 2011). Multiple factors contribute to math being a demanding subject for students throughout the educational pipeline. Learning math is cognitively demanding in that it necessarily employs various learning techniques, leverages visual and spatial ability, and uses specific cognitive strategies and critical thinking skills (Higbee & Thomas, 1999). This cognitive demand contributes to mental burden, which often manifests as math anxiety and may threaten academic self-concept, attitudes toward math, confidence in one's ability to learn math, perceptions of math's usefulness, and locus of control (Higbee & Thomas, 1999). Math anxiety constitutes a major barrier to success in math courses (Ramirez, Shaw, & Maloney, 2018).

In an effort to address these barriers, the U.S. Department of Education and What Works Clearinghouse issued a report (Bailey et al., 2016) outlining six recommendations for practitioners in assessing, advising, encouraging, and educating students struggling with math and in need of college remediation. One recommendation encourages differentiation of the curriculum such that students arriving with varied levels of preparation receive individualized instruction alongside targeted supports. Technology is a primary tool that can be harnessed to personalize student learning in this way. Technology-driven remediation presents an opportunity to individualize and accelerate learning, as well as to increase academic intensity for struggling students (Epper & Baker, 2009).

Individualizing and Accelerating Learning

The modularized format of teaching in a hybrid emporium classroom allows students to review material and demonstrate mastery before moving on to the next topic

(Bickerstaff, Fay, & Trimble, 2016). The adaptive nature of the software targets students' areas of need, allowing for increased time spent practicing in these areas and less time spent on topics already mastered. Consequently, students have the flexibility to take more time on topics when needed. Additionally, students, particularly the most vulnerable, may experience increased individualized academic support from instructors, as instructors have more time to respond to students' immediate questions and needs (Twigg, 2011). Individualizing instruction may also lead to more autonomy and self-efficacy in the classroom, which can, in turn, promote students' intrinsic motivation to perform tasks, sense of agency, and belief in their own competence (Ryan & Deci, 2000; Garcia & Pintrich, 1996). Evidence suggests that faculty encouragement of student autonomous action predicts greater self-efficacy and motivation in related tasks and learning (Black & Deci, 2000; Overall, Deane, & Peterson, 2011). Individualized learning also stands to save students time and money, as they need only retake the modules they have not yet passed rather than retake an entire course (Epper & Baker, 2009). This allows students to move through their courses more quickly.

Increasing Academic Intensity

In addition to offering students individualized instruction and the freedom to move through their developmental math courses more quickly, technology-driven courses like those using the hybrid emporium model are also potentially able to cover more content than a uniform semester-long course. Instructors may more efficiently help their students master skills and concepts through individualized learning programs that monitor student progress and adjust the content delivered accordingly (Hagerty & Smith, 2005). Students who are able to master basic course concepts are able to move on to more advanced material without waiting on their peers. These environments can encourage engagement in higher-order thinking and learning, as the technology is able to push students in the areas where they are least proficient (Babcock & Marks, 2010). This differentiation creates a classroom environment in which instructors may be assisting with a wide variety of mathematics topics, from the very basic to the advanced. In this sense, technology-driven instruction presents an opportunity for both increased rigor and pedagogical change.

Prior Research on Academic Outcomes

The academic benefits of accelerating learning and increasing academic intensity may explain some of the positive impacts of technology-driven instruction reported in the literature. Hagerty and Smith (2005) evaluated the efficacy of a particular web-based software in mathematics instruction by comparing the outcomes in four technology-driven college algebra classrooms with those in four traditionally taught classrooms by the same instructors in the same semester. They found evidence of short- and long-term gains: Students in the technology-driven classrooms had more skills growth during the semester and performed better on a standardized exam in their junior year (Hagerty & Smith, 2005). In a study of technology-driven instruction at 32 institutions that redesigned 86 developmental math courses, Twigg (2013) concluded that 83 percent of the redesigned courses showed significant improvements in end-of-course exams and subsequent course grades over traditional developmental math courses. And in a randomized controlled trial, Taylor (2008) found that technology-facilitated instruction reduced math anxiety and improved attitudes toward math among students after a semester, compared to control group students who took a traditional lecture-based course (Taylor, 2008).

However, not all of the research on technology-driven instruction has found positive impacts on student outcomes and attitudes. Common critiques of the approach include lower comparative responsiveness, less accountability, and the inherent distraction of self-driven, computer-based work. Students surveyed about computer-driven curricular redesign have reported a lack of instructor support (Epper & Baker, 2009). In the programs they profiled, students reported that they did not always want to teach themselves, and they found it difficult to collaborate with peers, as they were often working through different modules. While students may be open to using technology for formulaic tasks such as email or submitting assignments through online course management systems, research suggests that students may prefer person-to-person contact for more complex tasks such as course instruction and academic advising (Kalamkarian & Karp, 2017).

Another criticism of technology-driven instruction is that instructional modules are not consistent in the number of assignments given, amount of information covered, or difficulty of content. Research has shown that some modules are more content-heavy or more difficult for students than other modules and thus have lower pass rates (Fay, 2017). An evaluation of computer-mediated developmental math in the Virginia Community College System (VCCS) found that more than 80 percent of students had not completed the four required modules during a semester, and 42 percent had not completed any modules at all (Bickerstaff et al., 2016). Faculty have also reported a lack of deep learning on the part of students, perhaps because of the repetitive nature of practice and the style of assessment. They worry students may be able to perform well on the tests but cannot translate these important skills to other contexts, including higher-level math courses. Faculty also express concerns that institutions rely too much on technology to teach and support their neediest students, who might in particular benefit from more person-to-person interaction (Bonham & Boylan, 2011).

These issues may contribute to the negative findings on academic performance of students in hybrid developmental math courses compared to those in traditional courses. Research on students in hybrid emporium-style courses from community colleges in Tennessee (Boatman, 2019) and Kentucky (Kozakowski, 2019) has shown, in comparison to traditional courses, lower pass rates among students for subsequent college math courses, fewer number of credits completed over time, and lower associate degree completion rates. While these effects differ by student subgroup, the results overall suggest that the hybrid emporium model is not leading to improved academic performance for students in gateway college-level math courses.

The ultimate goal of instructional innovation is to improve both the academic development and classroom experience of students. While there is existing research on the impact of the hybrid emporium model on subsequent academic performance, there is little research examining how students experience technology-driven instruction. Despite mixed evidence of the model's effectiveness and a lack of data on student experience, the hybrid emporium model continues to be rapidly adopted across the United States for the facilitation of developmental mathematics learning. It is therefore key to understand how students experience this technology-driven instructional approach in order to inform implementation. Our research examines how students report experiencing a technology-driven instructional model in developmental math, with the goal of providing insight into why programs that use the model may or may not achieve their intended outcomes and how they might be improved to better serve future cohorts of students.

3. Conceptual Framework

Technology-driven instruction may change the way students experience developmental math courses by altering their learning environment. This change may influence the *cognitive* and *social* accessibility of math. Learning math in an instructional setting is both cognitive, in the sense of acquiring specific math skills, and social, as relationships that students form with actors in the classroom and the emotions they experience there may affect how students learn and their purpose and orientation. Students who perceive their faculty members as approachable and available have greater confidence in their academic skills and greater motivation (Komarraju, Musulkin, & Bhattacharya, 2010). Thus, while instructional change is implemented largely to increase students' cognitive accessibility to the material, technology-driven instruction's influence on the nature of teaching and learning in college-level developmental math could also lead to changes in students' attitudes and perceptions toward math and academic engagement. Taken together, the ability to access material continuously along with one-on-one attention from instructors and changes in the faculty-student power dynamic may fundamentally alter the relationships that students form with actors in their classrooms, which may ultimately serve to reshape their beliefs and feelings about math.

Cognitive Accessibility

The differences between the hybrid emporium model and traditional math instruction, especially in terms of instructional delivery and student access to course materials, may change the cognitive accessibility of math. Under the hybrid emporium model, students have access to math instruction at any time. Through videos, quizzes, and practice problems, the modules provide abundant opportunities for practice. Instantaneous grading and error identification provide immediate feedback. Whereas in other classrooms, questions must be held for class time, office hours, or tutoring, students in a hybrid emporium course can receive help from the online platform in real time or from the instructor via email or mobile application before the next class. Additionally, the online platform may present alternative strategies for solving problems and learning material, which provides students with a valuable complementary perspective that they might not receive in a traditional classroom.

Social Accessibility

Technology-facilitated instruction may also change the social accessibility of math, or the relationships that students form with actors in the math classroom, ultimately shaping their affective experience of learning math. Whereas in a traditional classroom, teachers spend the bulk of their time addressing the entire class, in a hybrid emporium classroom, teachers float between students, spending time with individual students to address their personal questions or to check on their progress, thereby altering the student-faculty relationship. This model fundamentally changes the power dynamics of a traditional classroom. Whereas in a lecture-driven classroom, instructors often function as the gatekeepers and purveyors of knowledge, in a hybrid emporium classroom, the online platform delivers material to students. This diffusion of content authority and the practice-driven nature of the material may ultimately have a democratizing effect.

Longstanding evidence suggests that faculty-student interpersonal relationships shape students' college experiences by contributing to skill development and engagement (Astin, 1977; Pascarella & Terenzini, 1976; Umbach & Wawrzynski, 2005). The reoriented classroom under the hybrid emporium model may offer faculty the opportunity to engage with students in more meaningful ways. According to prior research, students report higher levels of engagement and learning when faculty interact with students and use active and collaborative learning techniques (Umbach & Wawrzynski, 2005). Through individualized engagement with faculty, peers, and tutors, students may develop more autonomy (Chickering & Reisser, 1993). Changing the nature and frequency of interactions with faculty may, in turn, change students' perceptions, engagement, and development in the classroom.

Alternatively, there are some circumstances in a hybrid emporium classroom in which students may have fewer opportunities to engage with faculty or may do so in less meaningful ways. The expectation in a hybrid emporium classroom is that faculty and tutors circulate to answer student questions. Under this model, students may perceive that they have less contact time or a more tenuous connection to their instructor than under the traditional lecture model. Even in the context of their one-on-one interactions, students and faculty may find it more difficult to establish rapport and common ground in the absence of direct instruction. Student-faculty engagement may be particularly important for students with the lowest standardized test scores (Carini, Kuh, & Klein, 2006). Given the correlation between entrance exam scores and math placement, better engagement of developmental students could be particularly helpful for students' long-term outcomes. Community college students generally have lower levels of engagement with faculty, and their interactions with faculty are concentrated during class time (Chang, 2005). Chang recommends that instructors adapt their instruction to more frequently engage in discussion with students around material. Such an instructional adjustment may be accomplished through the individualized interactions built into a hybrid emporium classroom.

Students may also perceive differences in their engagement with their peers in the technology-based classroom. While working side by side at computers, students may communicate and help one another in different ways than they would while sitting in a lecture. They may make more substantive connections with classmates as they navigate the computer platform and negotiate with difficult material. Alternatively, while facing screens and working independently with expectations of silence, some students may find fewer or poorer opportunities to connect with peers.

4. Study Design and Sample

Our study uses a case study approach to answer the research question: *What do students report as the impacts of developmental math instruction through the hybrid emporium model on their academic and psychosocial experiences in college courses?* We collected our data in two phases: survey data collection and campus site visits. In the first phase, we administered a 35-question online survey for administrators and instructors during the summer of 2016 using the Qualtrics online platform. Survey questions focused on topics related to initial implementation and ongoing use of technology-driven instruction, including the degree to which instructors leverage the instructional platform, the logistics of implementing the model, and the proportion of incoming students who are required to take developmental math. The survey was distributed via email to administrators and instructors who serve as Tennessee Board of Regents developmental math coordinators at each institution, in order to seek perspective from the individuals most intimately involved with the implementation and management of the hybrid emporium instructional model (see Appendix Table A.1). After analyzing the survey responses, in November 2016 we contacted a purposive subgroup of institutions to maximize variation in timing and degree of implementation of the model among our sample for site visits.

From January to March of 2017, we conducted site visits at four two-year institutions and two four-year institutions (see Table 1). Sites were selected in order to achieve maximum variation to explore the potential heterogeneity of student experiences in the hybrid emporium model under different conditions. The four community colleges were different sizes and in different geographic settings, and their developmental math courses were all taught using the hybrid emporium model. The two four-year colleges also were different sizes and located in different geographic settings, They also used the hybrid emporium model, although not in a traditional prerequisite developmental math course format. At the four-year colleges in Tennessee developmental math is only offered as a corequisite course. Students in need of developmental math enroll in college-level math with an additional section dedicated to a review of the basic concepts. This one-credit section is taught using the hybrid emporium model. Through our visits to these six institutions, we aimed to capture the diversity of student perspectives at campuses that adopted the hybrid emporium model in their developmental math courses.

At each institution, we conducted hour-long interviews with one administrator and one instructor, observed a developmental math class taught using the hybrid emporium model, and facilitated a 60-minute focus group with two to eight students. All of the students who participated in the focus groups were currently enrolled in a developmental math course taught using the hybrid emporium model. Representatives from the math department at each college recruited student participants for the focus groups. Focus groups were scheduled in math classrooms during periods when math department representatives believed that most students could potentially attend based on institutional course-taking patterns. Students were offered an incentive of a $20 Amazon gift card for their participation. The open-ended, semi-structured student focus group protocol focused on the current experience of students in the classroom, as well as perceived benefits and challenges of different aspects of instruction and assessment, with particular attention paid to the use of technology (see Appendix B). We structured questions to minimize leading students toward particular responses. We asked overarching questions and relevant follow-up prompts when necessary.

Although we took care in the development of the protocol and participant recruitment, there was inevitably some selection bias due to the decisions that we made regarding our line of questioning and recruitment. Although we endeavored to offer equal opportunity for participation for all developmental math students enrolled in a hybrid emporium math course, the timing of the focus groups may not have been feasible for all students. Participants are largely self-selected, making it more difficult to generalize findings from the sample to the population of interest.

We chose to facilitate focus groups in order to generate a group discussion around each question, drawing from the experiences of multiple individuals at the institution rather than focusing in-depth on the experiences of one or two students. However, there are limitations to using focus groups relative to in-depth interviews. Participants may be disinclined to express unpopular opinions or potentially embarrassing experiences. It may also be difficult to ensure that the perspectives of underserved or hard-to-recruit individuals are represented. However, focus groups better suited our goals for the study for a number of reasons. Focus group participants could potentially be more candid, as they may be less inclined to provide responses that please the interviewer, which may be more likely to occur in a one-on-one setting. Additionally, participants can build on one another's ideas in such a way that constructs a detailed picture of the experience under study. And, rather than later finding that interviewees' experiences differed, the interviewer can probe consensus or lack of consensus on topics of interest in real time.

The primary data leveraged for this paper come from the student focus groups. While we must be careful not to overgeneralize findings based on the focus group conversations, it is also true that the participants, while small in number, represent a cross section of students in a hybrid emporium developmental math course and a range of student experiences. The students in our sample (see Table 1) are diverse in terms of their gender, race/ethnicity, and age. The focus group participants also vary by initiative and skill level. For example, when asked for the amount of time they spent on math in a given week, across the focus groups, students reported spending between 5 and 22 hours per week on math outside of class, with a median study time of 9 hours.

Table 1

Description of Site Visit Sample

Sector	Urbanicity	Undergraduate Population	Total Persons	Student Focus Group Characteristics: Race/Ethnicity	Gender	Age	Professional Participants
Public, two-year	Suburb	10,000–19,999	2	Black/African-American (2)	Female (2)	Traditional (2)	Faculty, department chair, developmental math coordinator
Public, two-year	Rural area	5,000–9,999	3	Black/African-American (2), Hispanic (1)	Female (1), Male (2)	Traditional (2), Nontraditional (1)	Faculty, curriculum chair, math lab coordinator
Public, two-year	Small city	1,000–4,999	4	Black/African-American (1), Hispanic (1), White (2)	Female (3), Male (1)	Traditional (4)	Faculty, former and current department chairs
Public, two-year	Midsize city	5,000–9,999	6	White (6)	Female (3), Male (3)	Traditional (4), Nontraditional (2)	Faculty, math lab coordinator
Public, four-year or above	Remote town	10,000–19,999	5	Black/African-American (2), White (3)	Female (3), Male (2)	Traditional (4), Nontraditional (1)	Faculty, department chair, math lab coordinator
Public, four-year or above	Large city	5,000–9,999	7	Black/African-American (6), White (1)	Female (4), Male (3)	Traditional (6), Nontraditional (1)	Faculty, department chair, math lab coordinator

5. Method of Analysis

For focus groups and interviews, we took notes and audio recorded during the sessions. After each site visit, we gathered field notes and discussed the visit. Each focus group or interview was transcribed verbatim. We then listened to the audio recordings and added field notes in order to integrate the observational data with the audio-recorded data. We entered data collection without preconceived notions about student experiences and underlying mechanisms and worked to minimize expectations throughout our analysis.

We leveraged a grounded theory analytic approach in order to better understand how students felt that their experience of enrolling in developmental math under the hybrid emporium model affected their learning and outlook, particularly in comparison to their experience of traditional instruction in other courses (Charmaz, 2006; Strauss & Corbin, 1990). We used an emergent, open coding approach in order to ground categories and themes in the data. We individually coded transcripts and then met to ensure systematic application of the coding process across transcripts and to compare and refine initial codes. We discussed and clarified the codes, resolved discrepancies, and used comparative analysis to identify themes, natural variation, and patterns that emerged across the transcripts during iterative rounds of coding. After we identified codes and themes in the data, we gathered additional understanding by triangulating data from our classroom observations and teacher and administrator interviews.

After the initial round of coding and discussion, we wrote preliminary memos that considered tentative themes that had emerged. In two subsequent rounds of coding, we employed axial coding to account for connections across themes. Through our discussions, we engaged in theoretical sampling, returning to the data to refine and validate our major themes. Once themes were finalized, we engaged in collaborative discussion and memo writing to explore how our themes were related to the existing empirical and theoretical literature. We integrated our memos and diagrammed connections between the emergent themes, identifying domains through an individual and team process. We converged on a set of domains that were validated by this iterative, triangulated process. Table 2 provides examples of the codes, themes, and domains that emerged from our data analysis. For instance, the domain of cognitive accessibility includes the emergent theme of *increasing access to material and support*, in which students expressed that the hybrid emporium model provided better opportunities than the traditional lecture format to engage with instructional material and concepts. This was distinct from themes that emerged in the domain of social accessibility, such as *deepening relationships between students and instructors,* where students described having more substantive interactions and deeper relationships with hybrid emporium instructors than instructors in lecture-based courses. We concluded our analyses once we had achieved informational saturation, as no new information and themes were emerging from additional cases.

Table 2

Examples of Data Coding and Theme Formation

Example of Raw Interview Data	Emergent Theme (Code)	Explanation of Code	Domain
"They will tell you what you did wrong and where did you mess up wrong, and [you can choose] 'Help Me Solve This,' and 'Have You Solve This,' 'Ask Instructor,' 'See an Example.'"	Increasing access to material and support	Students find greater opportunities to engage with instructional material and to find help in understanding concepts.	Cognitive accessibility
"You get to solve questions and if you need more practice you get to repeat it until you get it, and you're certified to know if you're really good at it before you take the test."	Affording abundant opportunities for practice	Students find model structure and platform contents provide plentiful problems to practice their skills.	
"You get instant gratification from it. As soon as you get done with the test, you don't have to wait [for feedback]."	Providing immediate feedback	Students immediately informed of incorrect answers and errors are explained.	
"So he's always there [in class and the math lab] to help out and answer any questions you've got, and he's always open for emails, too."	Multiple avenues for relationship between students and Instructors	Students have more opportunities to interact with faculty.	Social accessibility
"I can see how passionate and how interested she is. . . . She's sweet. I like her. She seems like a grandma to me, like but give me mom speeches."	Deepening relationships between students and instructors	Students and faculty have substantive interactions and form deeper relationships.	
"It like challenges you to work by yourself instead of asking the [instructor or tutor]. You can figure out how to do it yourself. . . . You don't rely on a person."	Empowering student agency through autonomy	Students have ownership, responsibility for learning and resources to meet that responsibility.	Breaking down barriers to math

6. Findings

While focus group participants were enthusiastic about the hybrid emporium instructional model overall, they did express some frustrations. Participants' enthusiasm for technology-driven math instruction was moderated by the inconveniences and inflexibility of the instructional platform and the pace of the course. In two focus groups, students discussed inconvenient aspects of the instructional model, focusing their attention on the hours of operation and seating capacity of the math lab, delayed nature of faculty responses to questions via email, and occasional malfunctions of the platform, particularly during assessments. Despite these criticisms, students in our focus groups still expressed overwhelming preference for technology-driven instruction, largely related to the ways a hybrid emporium developmental math course breaks down barriers to math by increasing cognitive and social accessibility. In this section, we describe students' perceptions of the impact of technology-driven developmental math instruction on their academic and psychosocial experiences in college courses.

The nature of the accessibility afforded by the technology-driven instruction can be categorized as cognitive, related to the acquisition of knowledge and understanding, or social, related to relationships and emotions. The themes that emerge from students' discussion under the domain of cognitive accessibility are: (1) access to math instructional content, (2) abundant opportunities for practice, and (3) immediate feedback on their performance. Students also remarked on the social accessibility of the mathematics curriculum, citing their (1) satisfaction with multiple avenues for relationships with their instructors and (2) deeper relationships with instructors.

The perceptions of accessibility are particularly important for developmental students because of their limited prior success with mathematics content. We note that the primary motivation for introducing technology-driven instruction is typically cognitive—this instructional innovation is intended to improve student understanding and mastery of mathematics concepts. The social accessibility of mathematics under the colleges' redesign using the hybrid emporium model constitutes a notable unintended consequence.

Finally, discussion we heard in the focus groups suggests that changes in access to content, practice, and support may contribute to overall shifts in students' perceptions of self, math, and even college itself. The focus group data reveal a possible connection between cognitive and social accessibility, on the one hand, and students' perceptions of barriers to math and their own agency in engaging in math learning, on the other.

Cognitive Accessibility

Students' access to additional materials and expert support, abundant opportunities for practice, and immediate feedback are the underlying experiences that contribute to cognitive accessibility of math under the hybrid emporium model. Our focus group participants explained that these features of the model contribute to their ability to utilize and feel empowered by the curriculum.

Increased Access to Material

Participants consistently remarked that they have more and better access to notes, resources, and academic instruction in a hybrid emporium course than in previous math courses they have taken. This increased access is reflected in one student's remark on access to material in and outside of the classroom:

> Everything done in class is online for us to look and go back and review for when we do our homework. So . . . if we have one problem we're stuck on, we can go back and do that, so that's something I noticed. The technology is a pretty big plus.

There was a pervasive sentiment among students that they can access and leverage material for their learning at any time. Students explained that the web-based platform allows for flexible access to content and support materials. Rather than waiting for the next class period for clarification or the delivery of new content, the web-based, self-paced nature of the course allows students to practice skills and access new material at will. Constant accessibility of course content and assignments may be better suited to students' schedules, particularly at two-year institutions where students are more likely to work and live off campus. One student said that this accessibility allows him to work forward when he has more time and ease off when his schedule is busier. He said, "Everything's already laid out for you, so you sort of know what's happening. If you got to go out of town you can go ahead and do some homework . . . so you don't fall behind."

Under the hybrid emporium model, students also enjoy flexibility in terms of where they can complete their assignments and assessments. In addition to completing modules and quizzes during the class period, students can continue their math instruction and assignment completion wherever they have an internet connection and a compatible device. Some students expressed a preference for completing their work during class and in the math computer lab, while others said they preferred using personal devices to complete their work at home or in other off-campus spaces. One student described dividing his math time between home and school: "I go home and do it, too. . . . I have more time at home than here, and I get a lot more stuff done. [So] when I come here I get to take the test or whatever, and I pass those, and I'm out." The technology-based instructional platform gives students the freedom to make choices about when, where, and how to learn content, a dramatic departure from a traditional lecture-based course. Students frequently referenced the math lab as a resource where they can seek help from professors and tutors.

However, instructional and practice resources are not uniformly accessible from home for students at some of the colleges we visited. At one campus—where instructors and administrators highlighted that students come from more limited means—students mentioned that they are limited in their ability to access these resources depending on their technology at home. One student explained that device compatibility is a limitation on the flexibility and accessibility of material: "You can do [homework] at home too, but it's really hard, because your computer has to have a certain thing for you to get it. So . . . if you've got an old computer it's kind of hard for you to get [logged] in." For students without Internet or a compatible device, progress and practice are limited to campus. This can be challenging, particularly for working students for whom the flexibility of completing assignments at home may be particularly helpful.

Students also perceived the pairing of technology-driven instruction and one-on-one support as presenting the opportunity to see math done in different, more accessible ways. In addition to teacher-led guidance, students also have ready access to technology-based resources, math lab tutors, and peers, all of whom may approach or explain math concepts and solutions in distinct ways. A number of participants remarked that they are able to better connect math to other academic work and their lives outside of school after having the opportunity to see math explained in different ways. One student expressed appreciation for the alternate perspective her teacher offered in addition to online and print resources, saying, "I liked the way she taught. . . . It's a way that she feels that maybe come to us better than what a book has. . . . So she breaks it down, and then online [there's] just more help." In addition to suggesting that the comprehensive supports of an invested teacher paired with online resources contributes to better teaching, this student suggested that the change in the instructional norms of the classroom liberates the teacher from adhering strictly to a textbook. Another student remarked, "I actually took this class [in traditional lecture format]. I dropped it the first time I took it . . . because my professor kind of did everything. . . . It wasn't really teaching us, it was just him rewriting what was in the book, and I didn't learn with him." Students expressed that the interactive nature of the platform, the alternative forms of practice problems, and instructor support all afford greater access to the material than in traditional mathematics courses.

Abundant Opportunities for Practice

Students overwhelmingly expressed satisfaction with the abundant opportunities for practice and the receipt of immediate feedback on practice problems. Instead of working through a finite set of sample problems drawn from worksheets or a textbook, the web-based platform can generate nearly infinite problems to hone a particular skill. One student commented on the benefits of such adaptive technology:

> In high school they gave you your homework in class and you'd finish it, and then you wouldn't have anything else to do. I mean, yeah, that's okay, but I'd rather go more in-depth with it than I did in high school. When we do math homework [on the web-based platform] and we got these options to like "Get another question" or "Do it again," it's like we're learning from our mistakes.

If students err while they work through practice problems, they are corrected with tailored prompts. When asked whether and how the platform promotes learning, students frequently cited the instantaneous feedback. They said that immediate feedback enables them to adapt their study methods and pushes them to redouble their efforts. Students reported using the instructional resources available to them to varying degrees, but most found them to be useful and empowering.

Students consistently expressed the value of practice-based learning, citing that repetition contributes to greater understanding. The practice sections that students are required to complete before beginning homework problem sets provide the opportunity to complete a seemingly infinite number of practice problems in order to feel more confident in their mastery before they are assessed. One student explained that, when tackling difficult material, "You have the option of either actually being walked through that particular problem, at which point at the end it'll give you a different problem, or you can choose to see an example of a similar problem and then you can even go to the text." For this student, constant access to step-by-step instructions contributes to a better learning environment. Students frequently mentioned this process of trial and error as a low-risk way of learning from their mistakes. In contrast to lecture-based courses where quizzes and exams serve as a single shot for demonstrating knowledge, the practice quizzes in the hybrid emporium model allow students to make mistakes and learn from those mistakes without academic consequences. One student summarized the benefits of continuing to learn from his mistakes:

> Actually going through the exercises and . . . being able to work something until you get the right answer just because like once you get to that point, it's kind of— it just clicks. . . . Like there might be something that I struggle with, and I might be stuck on a problem like number two for maybe like 30 minutes, and then . . . from doing it over and over again, I get it. I can breeze through like the next 15 questions, no problem.

Students perceived the wealth of practice problems from the hybrid emporium model as one of the primary ways in which the course concepts became more accessible to them, both inside and outside of class.

Immediate Feedback

Students reported the helpfulness of receiving feedback on their work immediately, as the online platforms identify whether a solution is correct and, if not, at what stage the solution went awry. This feedback enhances the accessibility of the material and contributes to students' ultimate mastery of math concepts. One student remarked:

> And it's so good to have like immediate feedback of what you did instead of doing something in class . . . and you might have to wait until the end of class to see if you've done something right. . . . It's a lot easier [when you] get immediate feedback of if you did something wrong or right, and why.

When asked as to whether and how the platform promotes their best, deepest learning or rote learning through repetition, students frequently cited the instantaneous receipt of feedback. One student remarked that the platform facilitates students' ability to identify and thoroughly remediate skills. She reflected, "I think . . . having that immediate feedback, like 'Hey, you got this answer wrong,' it's easier to go back and look and see where your mistake was and find holes in your understanding of the material." Students expressed confidence that the immediate and comprehensive help they get from the platform and instructors in combination is helping them master important skills.

Students felt that immediate feedback contributes not only to their concept mastery, but also to their development and utilization of study skills. The immediate feedback they receive on assignments and tests, in particular, gives them the help they need to adapt their study methods for success in this and other courses. One student pointed out the utility of immediate feedback in the hybrid emporium course for adjusting his plan for the semester, as compared to the slower feedback he received in another course:

> As soon as you get done with the test, you don't have to wait. . . . You get to see exactly what you made, and you can plan forward from that. So if you bombed it, you can say, "Okay, well, I'm going to have to work even harder for the next one starting now." . . . [In another class] I'm a week and a half from a test [but have not yet received the results], so I don't know if I did fantastic and I should keep my study methods or if I bombed that one and I need to change things up. It's a lot easier to be able to see if you're on the right path or if you need to step up.

The course schedule in traditional lecture-based courses typically does not allow for feedback as immediately as in a hybrid emporium course. Overwhelmingly, students reported that they like knowing where and why they are going wrong. While at times frustrating, this constant feedback loop provides a clear picture for students of where they stand in their math course at all times throughout the semester.

Social Accessibility

Students also expressed a preference for technology-driven instruction due to social connections with classroom actors that contribute to feelings or beliefs that the course and material are within their reach. Improvement along this psychosocial dimension was largely unintended and unanticipated by those in charge of implementing technology-driven instruction at the six colleges. Student discussion of the technology-driven instructional experience often focused on their communication, work, and relationships with faculty. Faculty-student engagement, both formal and informal, has long been identified as a key component of academic integration, which is a primary driver of student persistence (Astin, 1993; Chickering & Gamson, 1987; Hurtado & Carter, 1997; Pascarella & Terenzini, 2005; Stage & Hossler, 2000; Tinto, 2000; Tinto, Goodsell Love, & Russo 1993).

Our focus groups and observational data suggest that the hybrid emporium model disrupts traditional interaction patterns between faculty and students by providing support from faculty as "tutor resources" rather than stand-and-deliver sages. The social accessibility generated through these relationships may be particularly important for the success of academically at-risk students. For the lowest skilled students, previous academic experiences, particularly interactions with faculty, may not have been positive. The technology-driven instructional model may break down barriers through one-on-one or side-by-side interaction.

Multiple Avenues for Relationships With Instructors

Under the hybrid emporium model, students find multiple avenues for building relationships with faculty. They reported contact in class, in the math lab, through the instructional platform, via email, and via mobile application. Students reported that their instructors are facile with technology for interaction and that these interactions afforded opportunities to connect interpersonally and to share important content-related knowledge.

The instructional platform allows students to contact their teacher at any time during instruction or practice. Writing to the instructor directly from the web-based program when a student is having difficulty in solving a problem sends both the student's description of their misunderstanding and a screenshot of the problem they were solving and their work completed to that point. Students and teachers both expressed that this was a boon for efficiently communicating difficulties and sorting them out without in-person contact. When asked whether they ever hold these questions for office hours instead of sending them immediately, the majority of students expressed that they do not attend office hours, preferring to see teachers in the math lab (where faculty have required tutoring time) or communicate virtually.

Across institutions, students remarked that, through these various forms of interaction, they get to know faculty better and feel more comfortable asking them questions than in other college classes and in the past. Students consistently expressed that technology-based access to faculty enables them to seek help when and how they need it. Without the increased technology-based access to faculty, students may not otherwise be able to receive personalized assistance with instruction or practice outside of the classroom. Fortunately, students found that personalized attention is available to them not only in the targeted, immediate feedback they receive from the instructional platform but also in timely responses to digital inquiries they send to their instructors. In one focus group, two students discussed how they communicate with their shared instructor and how accessible she is via email:

> Student 1: If I ever have any questions, if I'm doing it at home, I just email her, and she'll try and get back to me as soon as she possibly can.
>
> Student 2: She's quick in emailing back too.

Sentiments like those expressed by these students were common. Students communicated that the quick and dedicated responses of faculty are helpful both in their understanding of the material and in developing their relationships. Consistent, compassionate responses to requests for help confirms faculty investment in student development.

Importantly, this contact between faculty and students is not only in response to student questions. Often, students remarked that faculty communication is proactive in nature. Some students noted that their technology-driven math instructors are in touch with them more frequently outside of the classroom than their other professors. One said, "He sends us more emails than . . . all my teachers combined. I at least get like two a day from him just about, like, 'If you want to come [to the lab],' 'if you need any help,' or 'if you need anything.'" Students had positive impressions about the ways in which their hybrid emporium instructors are proactive in their outreach and responsive to student contact. It's possible that this high level of accessibility is a product of the additional capacity that faculty have in the absence of lesson design and grading. Another potential reason is that faculty who are familiar with an online instructional platform are more inclined to reach out via email given their greater developed familiarity with the electronic resources.

In addition to their satisfaction with faculty responses to digital messages and proactive contact, students were also impressed with faculty commitment to giving in-person feedback. At most institutions, faculty are required to tutor in the math lab for a certain number of hours per week, which gives students increased access to instructors without the potential barrier of making an appointment or the potential intimidation of meeting a faculty member in their office. Overall, students were surprised by the accessibility of their professors, particularly given what they had been told about college while they were in high school. One student noted her surprise, “I think I like college way more than I like high school. . . . [Teachers in high school said that] ‘Teachers are going to be mean to you [in college],’ and, ‘They are not really going to care.’ Like, I literally came into college thinking that my professors were not going to help me at all.” Students consistently expressed that the accessibility of faculty in class, in the math lab, and via technology contributes to their instructors being overall more accessible and supportive than their high school teachers, and relatively more accessible than other college instructors.

Deeper Relationships With Instructors

The multiple avenues for contact and the frequency of contact contributes to students’ perceptions of deepening interactions between themselves and their instructors. Students across institutions spoke of their relationships with their instructors as being an instrumental piece of their experience in developmental mathematics. The importance of academic support and mentoring relationships with faculty is supported by a long-standing literature examining faculty-student interaction (see, for example, Pascarella & Terenzini, 2005).

Regarding their hybrid emporium courses, students described warm, influential ties to faculty and felt that faculty are invested in their development and are interested in them as individuals. Students across campuses used familial language to describe their connections to faculty. One student described how her math instructor’s motherly care and attention keeps her on track for academic success, stating, “She’s kind of like a mom sometimes. She really is! I swear. I get mom looks just from her when I miss school.” This student, and others in our focus groups, developed a strong emotional connection with her developmental math instructor that she did not feel with faculty in other classes.

Students said that the smaller class size in the math lab works to their benefit because of the individualized attention they receive from faculty. One student commented that, "The smaller the class means the more personal time you get one-on-one with the instructor. The bigger the class, the less time they're going to be able to really sit down with you and help you through a problem." This student identified the utility of the hybrid emporium model's small class size for increasing personalized attention. The math lab format itself also gives faculty the opportunity to provide the one-on-one, sit-down instruction that students identified as important for their skill development.

Students appreciated faculty assistance and relationship building so much that a number of them recommended that developmental math students be assigned to both their developmental and college-level courses with the same faculty member. One student commented:

> I have the same professor for both, for [developmental math] and for my [college-level] class, which really helps, because you can ask her questions about either one when you're in either class. So if you've been having problems with the homework in [college-level], you can ask her while you're in [developmental math], and then she'll do it on the board and go over that lesson again with you in [developmental math].

Another student from the same institution, upon hearing this, voiced a recommendation: "I think it would be beneficial to have the same professor for [both classes]. I know that might be hard to do, but . . . then you have the opportunity to ask in either direction." Both students expressed a preference for having the same instructor in both their developmental and college-level math classes, pinpointing reasons of rapport and shared understanding for this recommendation.

Faculty-student relationship benefits are not limited to the student's assigned instructor. At institutions where math faculty work in the math lab alongside tutors, students also are able to meet and get to know other instructors. Students viewed this as an added benefit. Other faculty members might present the information in a way that makes more sense to them, or offer helpful perspectives on future coursework or the institution on the whole. In this way, students may gain exposure to a faculty member or discipline that they would not have learned about otherwise.

The social accessibility afforded by the model shifts the nature of student-faculty relationships, as discussed above. In turn, connections to faculty contribute to changes in students' perceptions of themselves and mathematics, as well as their college and career goals. We heard from many students in our sample, perhaps unsurprisingly given their enrollment in developmental math, who had previously been intimidated by math or unengaged by the content. However, students across campuses noted that they connected with faculty during early challenging moments in the course and were able to harness faculty support and the nature of the instructional model to turn around their performance.

Students remarked that their professors have shaped their relationship with the course material. Instructors play a role in lowering barriers to math and shaping students' academic pathways. One older student reported, "Before I got here, math was not something I liked doing. I hated math. I literally cried through the first two weeks of school. . . . And it was when I met with my math support teacher during her office hours and took the time to get a little bit of one-on-one that everything clicked. And now, I mean, I want to get a math degree." Increasing the cognitive and social accessibility of mathematics can have powerful consequences for perceptions of self and of the material, and faculty relationships are central to this evolution.

Breaking Down Barriers to Math

Students felt that technology-driven instruction lowers barriers that they had faced in prior math instruction, which leads to students feeling more empowered and more like success is within their control. One way this manifests is in students changing their math-related behavior. Students cited the requirements of technology-driven math courses as an important impetus that pushes them outside of their typical patterns of behavior. Students from multiple institutions suggested that as a function of being required to spend time in the math lab, they spend more time on math work and leverage important resources. They reported that they ultimately began to see math as less intimidating. The requirement and their subsequent exposure leads to opportunity and habituation such that their perceptions of their abilities and environment change. One student commented:

> I enjoy the fact that we were kind of forced into the math lab, because otherwise I would have been way too intimidated to go into it. Kind of like a girl going to the gym to lift weights: Like we want to do it, but we're afraid we're going to look stupid. . . . Because I hear math lab, and I think, "There's a bunch of geeky people in there, and that I'm . . . going to stick out like a sore thumb because I don't know what pi is," you know? And so being in there for my math support class kind of helped to make that a less intimidating environment.

This student said that previously she had not felt welcome in math-centered spaces because of her low relative skill level and identity as a non-math person. The requirement to go to math lab and the welcoming environment and support she received there have flipped the story: She now feels empowered to use the math lab, a space that she would have perceived as "off limits" otherwise.

Empowering Student Agency Through Autonomy

Students were eager to share about how the format of the hybrid emporium model puts the onus on students to get through the material and seek additional help when needed, which may serve as a mechanism by which students perceive barriers to math to be lower. Students felt that the self-paced nature of the technology-driven modules is more conducive to the different rates at which individuals learn material than the traditional classroom environment. One student conveyed that he felt more at ease with the pace and better-equipped to tackle the material as a result of the autonomy he was granted to learn the material:

> You don't have to rush as much. You make sure you really get it before you move on. . . . If you don't get it, you won't progress, and—I mean, like it's not somebody breathing down your neck trying to get you to do this, do this, do this. Make sure you get it, understand it, move on. Because we all learn at different levels. It's not just one class pace.

Another student supported this sentiment when reflecting on challenges he faced keeping up with material in a more traditional math course: "I don't really understand in the classroom what we're doing, because it's just so fast. I can't really keep up. I'm not able to process everything that's really going on, and it's like once you miss a step when you're taking notes for math, you don't understand it." Several students reported feeling less overwhelmed by the pace in a hybrid emporium classroom when compared to the pace of some of their more traditional courses.

While students remarked that the nature of hybrid emporium instruction gives them ownership over their learning, this self-paced and self-motivated approach can be a double-edged sword. One community college student discussed the benefits and challenges of students being given the responsibility of pacing their movement through the material:

> It's like a blessing and a curse. . . . This [course] is specific lessons that you have to do, which you could get them all done a week in advance, or you could fall behind on one lesson and it makes the other lessons harder on you.

Increased autonomy along with increased access to instruction, practice material, and support appear to shape hybrid emporium students' perceptions of self and of math, affecting their actions as a student, both in their developmental math courses and other college courses.

7. Discussion and Conclusion

The students in our sample reported cognitive and social accessibility benefits of technology-driven instruction. And they perceived having a greater sense of responsibility for their own learning as well. Our analysis reveals that these benefits are rooted in access to material, support, and relationships that empower students to succeed and offer the feeling that success is within their locus of control. Students reported that the hybrid emporium model increases their access to instructional material and support, provides abundant opportunities for practice, and connects them with immediate feedback. These underlying experiences contribute to the cognitive accessibility of math in the redesigned curriculum. Our focus group participants explained that these features contribute to their ability to utilize the platform and feel empowered under the hybrid emporium model of instruction. These experiences align with the goal of the model: to improve the student learning experience in developmental math courses.

While the purpose of this instructional reform is focused on cognitive accessibility, we also observed an unintended consequence—the model serves to open up multiple avenues to connect with faculty and to deepen faculty-student relationships. Our analysis suggest that the model disrupts traditional interaction patterns between faculty and students by reducing formal barriers between them. This evidence, drawn from the student perspective, stands in contrast with previous findings indicating that teachers perceive that technology-driven models may contribute to declines in classroom interaction and support (Natow, Reddy, & Grant, 2017; Groff & Mouza, 2008).

Our findings suggest that the hybrid emporium model takes the primary onus of instruction off the faculty, giving them flexibility to better support students inside and outside the classroom. Faculty spend the class period floating between students to provide one-on-one support. The hybrid emporium model provides instruction and abundant opportunities for practice, so faculty are able to concentrate their efforts on "spot treatment" of challenges and misunderstandings that arise as students work independently through the modules. The reduced instruction and grading load may allow them to be more responsive via email, instructional platform messaging, and mobile application. At the majority of institutions, students noted their appreciation that faculty are required to staff the math lab, as this also gives them access to faculty tutoring support. Interacting with faculty in these more informal settings allows students to feel more at ease seeking out help.

The social accessibility of math as it relates to improved interactions with faculty is supported by the faculty-student engagement literature. Faculty-student engagement is a key component of academic integration and contributes to student persistence (Astin, 1993; Chickering & Gamson, 1987; Hurtado & Carter, 1997; Pascarella & Terenzini, 2005; Stage & Hossler, 2000; Tinto, 2000; Tinto, Goodsell Love, & Russo, 1993). Students who arrive at college underprepared for postsecondary mathematics work are most at risk for dropout and disengagement from academic material. Student-faculty engagement may reinforce students' place in the academic fabric of the institution. Instructors can be change agents in the classroom: Their instruction and engagement with students can change the cognitive relationship that students have with academic content and can shape students' beliefs, emotions, and perceptions about math (Wang, Sun, & Wickersham, 2017). Given the dropout risk profile of students in developmental courses, the social accessibility generated through these relationships may be particularly important for student success.

Students in developmental coursework represent the plurality of community college enrollees and are the most vulnerable for dropout. Oftentimes, under alternative course structures, students find themselves caught in a prescribed developmental math sequence, unable to proceed to college-level coursework. The instructional redesign involved in transitioning to the hybrid emporium model, which reshapes perceptions of the cognitive and social accessibility of content and supports, should help to bolster students and empower them to succeed. Yet recent research finds negative effects of technology-driven instruction on students' subsequent academic performance (Boatman, 2019; Kozakowski, 2019). Therefore, we question why our participants articulated such benefits and general enthusiasm when quasi-experimental estimates from Tennessee suggest that, in comparison to students taking traditional developmental math courses, hybrid emporium students have lower pass rates in their subsequent college math courses and fewer credits completed over time (Boatman, 2019).

We find some guidance on this matter in the literature. It is possible that students' positive experiences with the hybrid emporium instructional model feed into a mechanism that is unrelated to academic performance. College student experiences of classroom autonomy may be more closely related to motivational factors than to performance (Garcia & Pintrich, 1996). Although students may not perform better in the course or remain enrolled in college longer, the experience of autonomy may foster intrinsic motivation and self-efficacy, which may prove useful in other collegiate contexts not captured by traditional measures of student performance such as course grades or persistence.

Additionally, the perceived benefits regarding cognitive and social accessibility may not yield large enough changes in self-efficacy, math content knowledge, or other benefits to boost performance for students in developmental math. Meta-analytic analysis of 39 studies of self-efficacy and academic performance found that self-efficacy beliefs account for approximately 14 percent of the variance in students' academic performance and approximately 12 percent of the variance in academic persistence (Multon, Brown, & Lent, 1991). However, much of the literature focuses on self-efficacy in elementary and secondary school students or among postsecondary students in college-level coursework. Additional investigation into the explicit relationship between self-efficacy and course grades among young adult and adult students in developmental coursework would shine light on a potentially important mechanism for understanding performance in this student population. Further, simply because students report that math concepts are more accessible to them in a hybrid emporium course does not necessarily mean that students are improving in their understanding of these concepts. While students may feel as if math is easier to learn in a technology-driven classroom, a comprehensive assessment at the beginning and end of the course would provide evidence on actual as opposed to perceived learning gains.

The limitations of this study are similar to other case study analyses. First, the institutions where we conducted site visits and the students with whom we spoke constitute a purposive sample. While we selected institutions from a range of geographies and asked administrators to recruit a diverse group of students, there are limits to the generalizability of our findings. Selection also plays a role with respect to who teaches hybrid emporium model math courses. At some institutions, teaching developmental courses is required, while at others faculty select their course assignments. Notwithstanding these limitations, we find consistent, emergent themes based on how students in our focus groups reported their experiences in the classroom.

In this study we did not focus on the experience of students through the lenses of gender, race/ethnicity, or other characteristics due to the small sample of students. We acknowledge that students' backgrounds play an important role in their in-class experiences and thus are likely central to the experience of any instructional innovation. Future research should focus in particular on the role of race/ethnicity, gender, age, socioeconomic status, and other student characteristics on student experiences in and perceptions of technology-driven developmental math instruction (Wang et al., 2017).

While this paper focuses on student experiences rather than student outcomes, the outcomes-focused literature is mixed on the effects of this and similar models that use an online instructional model (Alpert, Couch, & Harmon, 2016; Bowen, Chingos, Lack, & Nygren, 2014; Xu & Jaggars, 2013). While some studies have null or positive effects, on balance, the evidence suggests that technology-driven remediation is negatively associated with college mathematics success and future attainment. The results of the outcomes-focused literature are not consistent with the perceptions that students have of their experiences and raise interesting questions about the lack of alignment between the positive student experience of hybrid emporium math and the lackluster outcomes (Boatman, 2019; Kozakowski, 2019). It may be the case that there are other, larger barriers to developmental math learning that are not addressed by this model. The accessibility boons of this instructional model may engage and empower students while still falling short of what developmental mathematics coursework must accomplish in terms of skills and content mastery. Our findings suggest that there are positive unintended consequences of technology-driven mathematics instruction, but these changes do not necessarily lead to improved course performance.

Students' positive perceptions of the cognitive and social accessibility of their hybrid emporium coursework also raise the question: Are negative medium- and long-term relationships between such models and student outcomes due to drop-offs in the quality of instruction, supports, and relationships in subsequent math classes? Given the positive experiences of students with increased access to material and feedback and increased time and more avenues to connect with faculty and receive individualized support, we urge faculty and policymakers to consider ways in which curricular redesigns may be employed to put more material in the hands of students and preserve instructor time for greater personalized support and stronger relationship development. The continued study of students' experiences in developmental math coursework, particularly in classrooms and at institutions that employ innovative instruction, is critical to the success of postsecondary students and of interest to the institutions that serve them.

Appendix A: Supplementary Table

Table A.1

Description of 2016 Survey Sample and Participants

Sector	Urbanicity	Undergraduate Population	Math Remediation Rate (%) For First-Time Students*	Survey Completer
Public, two-year	Remote town	1,000–4,999	61–70	Developmental math coordinator
Public, two-year	Remote town	5,000–9,999	51–60	Director of institutional effectiveness and planning
Public, two -year	Remote town	5,000–9,999	51–60	Developmental math coordinator
Public, two -year	Suburb	10,000–19,999	41–50	Department chair and developmental math coordinator
Public, two -year	Suburb	5,000–9,999	61–70	Developmental math coordinator
Public, two -year	Rural area	5,000–9,999	61–70	Curriculum chair and math lab coordinator
Public, two -year	Rural area	5,000–9,999	41–50	Department chair
Public, two -year	Small city	1,000–4,999	61–70	Dean, math & science
Public, two -year	Small city	1,000–4,999	61–70	Department chair
Public, two -year	Small city	5,000–9,999		Developmental math coordinator
Public, two -year	Midsize city	5,000–9,999	51–60	Department chair
Public, two -year	Large city	5,000–9,999	71–80	Dean, division of math and natural sciences
Public, two -year	Large city	5,000–9,999	71–80	Department chair
Public, four-year or above	Remote city	10,000–19,999	41–50	Faculty member and math lab coordinator
Public, four-year or above	Small city	10,000–19,999		Faculty member and math lab coordinator
Public, four-year or above	Midsize city	10,000–19,999		Developmental math coordinator
Public, four-year or above	Midsize city	20,000 and above		Faculty member
Public, four-year or above	Large city	20,000 and above		Faculty member
Public, four-year or above	Large city	5,000–9,999	71–80	Faculty member and math lab coordinator

*Survey completers were asked, "Approximately what percentage of your institution's first-time students are assigned to developmental math" with choices 0-10, 11-20, 21-30, etc. At the four-year colleges in 2016, developmental math was offered only as part of a corequisite math course (college-level combined with developmental). Four of the survey respondents did not distinguish developmental math from college-level math, and did not complete this question.

Appendix B: Semi-Structured Protocol for Student Focus Groups

1. Please describe the math class in which you are currently enrolled (instructors, classroom setting, required hours, assignments, number of students per section, etc.)
    a. Describe what a typical session in lab/class looks like. What do you do? How many people are there?
    b. Do you ask questions? Are your instructor's answers helpful?
    c. When you raise your hand, how long is the wait for your instructor to get to your question?
2. How do you use technology in class?
    a. How does this differ from your other classes this term? From previous math courses?
3. What is most beneficial to you about the format of this class? What is the most challenging?
4. How many lab/classroom hours are required?
    a. Should all students be required to spend the same amount of time in the lab? If not, why not? If so, how many hours should be required?
    b. Does your teacher encourage you to come to lab hours? If so, how?
5. How have you used the math skills that you have learned from this course in your other classes or in your life outside of school?
6. Does the material in this class repeat the material you have learned in other courses in high school or in college? If so, is this repetition helpful or boring?
7. How does this classroom model promote your best learning as an individual student?
8. Does the individual pacing of the class make you work through the material more or less quickly than in other math classes you've taken?
9. Do you have more or less interaction with your instructor than you have had in previous math courses or other courses at this institution?
10. How does the difficulty of the work and time required for this course compare to a traditional three-credit course?

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