PROMISING PRACTICE

The Digital Shift: Is the Trend of Transferring Developmental Mathematics Coursework to Computerized Adaptive Learning Environment Effective?

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Developmental mathematics courses play a critical role in ensuring that students have the foundational mathematical skills necessary to succeed in higher educational mathematics coursework. With the introduction of the corequisite format in recent educational reforms, there has been a growing trend towards transferring developmental mathematics courses to computerized adaptive learning platforms such as computer aided instruction (CAI) and mastery-based learning for developmental math content. While this trend has led to increased accessibility and flexibility for students (Allen & Seaman, 2010; Spradlin & Ackerman, 2010), it has also raised concerns about the effectiveness in supporting student' acquisition of essential mathematical knowledge, particularly for the students categorized as needing developmental mathematics.

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Because these platforms require students' self-engagement with the content, it is essential to investigate how these platforms could possibly be utilized to promote more profound learning and cater to the specific needs of this student population.

Studies have indicated that students enrolled in developmental courses especially struggle in a fully online learning environment due to limited self-directed learning skills, lack of self-motivation to complete tasks, weaker academic preparation, insufficient time management skills (Xu & Jaggars, 2013), and lower levels of prior academic achievements (Asarta & Schmidt, 2017). Furthermore, research has shown that students' acquisition of knowledge is impacted by their level of motivation, attitude, sense of control, and perception (Blair, 2006; Núñez-Peña et al., 2013). Spradlin and Ackerman (2010) emphasized the importance of addressing math anxiety, negative mindsets, inadequate study skills, and lack of accountability for learning among students enrolled in developmental math classes.

These findings suggest that the mode of delivery is crucial for developmental mathematics content, and it raises concerns about the potential challenges associated with relying solely on computerized adaptive learning platforms for developmental mathematics coursework. For instance, some students may struggle with the lack of face-to-face interaction with instructors and peers, which can make it harder to receive personalized feedback and support. Additionally, relying solely on computerized platforms can limit opportunities for students to engage in collaborative learning, which can be an important component of mathematics education. Although we acknowledge the advantages of computerized platforms, such as immediate access to student progress and tailored instruction for students, we advocate for the use of these platforms alongside alternative teaching methods rather than as a substitute for in-person instruction and interaction.

Demystifying the World of Developmental Math

Research has regrettably shown college readiness in math has been the greatest obstacle preventing student persistence and degree completion rates of various student populations, with higher percentages among minority populations (Weisburst et al., 2017; Zientek et al., 2013). Who are the students enrolled in developmental mathematics? Developmental mathematics students are students assessed as unprepared for postsecondary mathematics as determined by their state standards, for example, Texas Success Initiative Assessment (TSIA) score or diagnostic score in mathematics (Texas Education Agency [TEA], n.d.). Postsecondary math course trajectory is determined by these benchmark scores. In Texas, students whose scores meet or exceed the benchmark scores are classified as college ready and can enroll in any introductory college course (such as college algebra) without needing developmental educational instructions (TEA, n.d.).

Prior to reform efforts, students deemed as underprepared languished in multiple semesters of non-credit bearing developmental courses, before enrolling in the traditional credit bearing algebra to calculus route (Bailey, 2009; Bonham & Boylan, 2011). In an effort to address this major concern, recent research focus has shifted to developmental education (DE) reform initiatives which incorporates augmenting coursework with study skills, adding tutoring resources, building learning communities, compressing or accelerating courses through accelerated learning programs (ALP) like emporium models, or pairing DE courses with college-level courses, and incorporating technology-corequisite model (Bailey, 2009; Bonham & Boylan, 2011; Cousins-Cooper et al., 2017; Hodara et al., 2012).

Understanding Developmental Math and its Impact on Student Success

Developmental education programs exist to bridge the gap for students who arrive at college needing additional academic support. These programs aim to strengthen foundational skills, particularly math, a crucial building block for further college-level coursework (Attewell et al., 2006). Unfortunately, research shows that math has the highest rate of students needing remediation among first-year students (Attewell et al., 2006) and the lowest completion rate for these developmental courses (Bonham & Boylan, 2011). This highlights a potential challenge in ensuring students are adequately prepared for the demands of higher-level mathematical studies.

Computer Aided Instruction in Developmental Math Coursework

A key rationale for adopting CAI in developmental mathematics coursework is its ability to provide students with individualized learning experiences. Most developmental math courses across the nation use computer programs like ALEKS, MyLabMath and Emporium models (Kasha, 2015). Assessment and Learning in Knowledge Spaces (ALEKS) is an AI-powered system designed to evaluate a student's understanding of a specific subject through adaptive questioning. It then generates a customized learning plan to address any areas of knowledge deficiency (Kasha, 2015). MyLabMath is an educational software that complements textbooks by offering students online tutorials, homework assignments, quizzes, and more resources to help them address their learning gaps (Kasha, 2015). When students start with such computerized software, an initial assessment is conducted from the software to determine what the students know and where the gaps are in their content knowledge. This artificial intelligence software is then able to guide the students from where they are to where they need to be with reference to content mastery (Ali, 2018; Mireles et al., 2014). Studies show that computer assisted instruction offers students the advantage of learning on their own schedule and receiving immediate feedback on their progress (Spradlin & Ackerman, 2010). Students have the opportunity to revisit the same concept multiple times until they achieve mastery and develop confidence (Brothen & Wambach, 1999). Furthermore, Canfield (2001) found ALEKS can be an effective supplement to traditional classroom teaching, providing students with feedback and allowing them to work at their own pace.

Concerns and Challenges for Technology Use in Developmental Math

Although these platforms can be effective tools for certain students, there are concerns about how effectively they serve students categorized as needing developmental mathematics coursework. It is critical to further emphasize that the population of students who require developmental mathematics courses often face a variety of challenges previously noted, including inadequate study skills, low-income backgrounds, being the first in their family to attend college, limited English proficiency, and insufficient academic preparation in high school (Attewell et al., 2006; Bailey et al., 2010).

Mireles et al. (2014) indicated that developmental math students often lack not only mathematical content knowledge but also study skills. Attewell et al. (2006) discovered that students who attended high schools with low levels of academic preparation were more likely to require remediation in college. Furthermore, Bailey et al. (2010) found that students who come from low-income families, are first-generation college students, or have limited English proficiency are more likely to require developmental education in college. These findings raise concerns about whether fully computerized adaptive learning platforms can effectively support this diverse student population. The challenges faced by these students can be further exacerbated by issues such as internet accessibility, administrative vulnerabilities and limited instructional software support. Given these challenges, we must rethink whether the trend of transferring developmental coursework solely to computerized platforms is a viable solution for students assigned to developmental mathematics.

Relying solely on computerized platforms can limit opportunities for students to engage in collaborative learning.

Importance of Human Interaction in CAI in Developmental Math

Relying solely on computerized platforms can limit opportunities for students to engage in collaborative learning. Xu and Jaggars (2013) found that students who completed developmental mathematics courses entirely online had lower success rates compared to those who completed the same courses in face-to-face settings. The study suggested that the lack of face-to-face interaction with instructors and peers may have contributed to the lower success rates. In-person instruction and interaction can provide students with important opportunities for asking questions, receiving feedback, and engaging in collaborative problem-solving activities. Kinney (2001), Tichavsky et al. (2015) and Vanoli and Luebeck (2021) studies revealed that students tend to prefer traditional instruction because it enables them to ask questions, seek clarification, engage in more human interaction, and receive feedback from teachers. Moreover, face-to-face interaction can provide students with important emotional and motivational support, which is crucial for their success in mathematics course work. Studies show that emotional and motivational factors, such as self-efficacy and anxiety, play a crucial role in students' success in mathematics courses (O'brien et al., 2010; Pajares & Miller, 1994).

Research has shown that collaborative learning and peer-to-peer interactions can have a positive impact on students' engagement and motivation in mathematics. For example, a control treatment study by Tran (2019) found that students who participated in collaborative learning activities in mathematics had higher levels of motivation and reported more positive attitudes towards math than those who did not participate in such activities. Similarly, Kumar (2017) conducted a meta-analysis to measure the effect of collaborative learning on student achievement. They not only found that students who engaged in collaborative learning had higher levels of achievement in mathematics compared to those who did not, but found that group activities and discussions were shown to help students develop communication skills and build confidence in their mathematical abilities.

A study by Karali and Aydemir (2018) found that students who participated in group problem-solving activities in mathematics reported improvements in their communication skills and were more likely to take risks in solving mathematical problems. An experimental study by Barham (2002) to examine the effectiveness of employing cooperative learning strategies in the mathematics classroom, particularly in terms of their impact on problem-solving abilities and levels of achievement in mathematics with 348 eighth-grade students over the course of two consecutive semesters, suggested that cooperative learning significantly improved students' mathematical achievements and problem-solving skills, compared to the control group. Furthermore, findings from the same study also indicated that cooperative learning fostered the development of other skills such as improved student engagement, successful interactions with peers, and the acquisition of competent social skills. Corporative learning has fostered a more favorable disposition towards the learning process, surpassing the outcomes achieved by control condition students. These findings suggest that incorporating other instructional techniques like collaborative and cooporative strategies improve cognitive, competitive and social interaction among students, thereby developing outcomes in the cognitive, affective, motivational, and social domains. Findings from studies by Sofroniou and Poutos (2016), and Zhang (2024) are consistent with Barham's (2002) research, reinforcing the notion that collaborative learning plays a critical role in promoting students' learning. Therefore, incorporating collaborative learning and peer-to-peer interactions in mathematics instruction can be an effective way to enhance students' engagement, motivation, communication skills, and confidence in their mathematical abilities.

Multiple Modalities of Learning Transformation

Research support for teaching mathematics through a single modality, such as lectures, textbooks or computerized tools, is not effective for all students. Some students learn better through visual aids, while others need hands-on experience. Therefore, incorporating multiple modalities in teaching can help cater to different learning styles, making learning more accessible and engaging (Lugosi & Uribe, 2020). Visual aids, such as graphs, charts, and videos, can help students visualize mathematical concepts and make them more understandable (Guo et al., 2020). A study by Berthold and Renkl (2009) found that the use of multiple representations, such as diagrams and equations, can help students have procedural understanding of abstract mathematical concepts like probability. Real-world examples and scenarios can also help students connect mathematics to everyday life, making the subject more relatable and relevant. A study by Chavez and Lapinid (2019) on using real-world examples in teaching mathematics found a statistically significant difference on students' motivation, engagement, and mathematical performance. Incorporating technology in teaching mathematics has also been found to be effective on student outcomes. Results from Cheung and Slavin's (2013) meta-analysis to investigate the effectiveness of educational technology applications in enhancing mathematics achievement in K–12 classrooms suggested that technology integration in general has a positive but modest effect on mathematical achievement. Another meta-analysis conducted by Li and Ma (2010), in order to find the effect of computer technology on school students' mathematics learning, found that computer technology has a greater effect when combined with a constructivist approach in teaching. Further studies conducted by Mireles et al. (2014) indicated that the integration of technology can help students placed students in developmental mathematics acquire a deeper understanding of mathematical content. For instance, academic performance gains were reported in two of the four lesson plans utilized in their study, with no academic drop in performance detected from other lesson plans used in the study. The authors noted that the quadratic equation lesson plans, with the utilization of familiar technology produced statistically significant results on the understanding and use of mathematical material immediately taught and reviewed. This solidifies that incorporating technology in teaching can provide students with additional opportunities to practice and learn mathematical concepts, which can improve their motivation, engagement, and performance in math classes.

Successful Integration of Technology in Developmental Math

Research shows that the combination of online and face-to-face instruction can lead to better student outcomes than either approach alone. For example, at Black Hills State University, a redesign of the college algebra course incorporated a computer-based mastery learning program alongside increased whole-class discussions, cooperative learning activities, and application problems while reducing lecture time (Hagerty et al., 2010). This initiative led to significant improvements, including a 21% increase in passing rates, a 300% rise in enrollment for the subsequent math course (trigonometry), a 25% enhancement in attendance rates, and statistically significant growth in collegiate assessment of academic proficiency scores. This success underscores the potential of integrating technology and collaborative learning methods to enhance student performance and engagement.

Other studies, such as those by Babcock and Marks (2011) and Martinez and Martinez (1999), further support the efficacy of combining online platforms with traditional instruction. Babcock and Marks (2011) emphasized the importance of using technology to reinforce conceptual understanding rather than simply providing quick answers. Martinez and Martinez (1999) highlighted the significant impact of expert guidance in mastery learning settings. Thus, while computerized systems like ALEKS offer valuable support, they should complement rather than replace human interaction in the learning process. The combination of technological platforms and human interaction fosters an effective learning environment that promotes student success.

> Studies suggested that a blended approach combining online platforms with face-to-face instruction yields better student outcomes than either approach alone.

Within a prior edition of this journal (*Journal of College Academic Support Programs)*, Lollar and Pipper (2023) conducted an interview with Stevens from Austin Community College District, emphasizing the seamless integration of technological platforms such as ALEKS into mathematics classes that enhance student learning. In the interview, Stevens emphasized the transformative nature of the ACCelerator at Austin Community College's (ACC) Highland campus, which utilizes technology alongside traditional teaching methods to support student engagement and learning. One particularly notable aspect is the implementation of the SEDI (Student-Engagement-During-Instruction) philosophy, which prioritizes student-teacher interaction during instruction, proving especially effective in building relationships and engaging male and minority male students. These findings highlight the importance of technology as a supplementary tool for learning, rather than a complete replacement for face-to-face interaction between students and teachers. It aligns with the ongoing debate about whether computerized adaptive learning environments are truly effective for students needing developmental mathematics courses. The ACCelerator's success in promoting personalized instruction, student engagement, and persistence in mathematics education underscores the potential effectiveness of such an initiative, provided it is implemented thoughtfully and in conjunction with other teaching methods. Thus, the integration of computerized adaptive learning environments holds promise for improving student outcomes in developmental mathematics while preserving essential aspects of face-to-face instruction and interaction.

Promising Practices for Developmental Mathematics

As we have articulated in this paper, students enrolled in developmental education programs require a comprehensive approach to developmental mathematics instruction. This necessity arises from the multifaceted challenges faced by students in these classes, spanning cognitive, affective, and behavioral domains. Factors such as negative experiences in K–12 education, inadequate support systems from both family and school, and deficiencies in study skills contribute to their placement in developmental education (Bettinger et al., 2013).

While the implementation of corequisite formats and similar streamlined processes has enhanced developmental education, there remains an imperative to provide robust support to students within these programs (Bickerstaff et al., 2022). We advocate for a model that combines computer-aided instruction with teacher-led classroom or laboratory sessions. This hybrid approach offers students invaluable opportunities to engage with peers, connect with instructors, and cultivate a conducive learning environment.

For educators and institutions committed to fostering student persistence and success in attaining college degrees, we urge against simply transferring developmental math content to computer-adaptive, student-led coursework. Instead, we advocate a pedagogical framework that integrates technology with teacher-guided instruction, thereby facilitating a more interactive and supportive learning experience for students. By adopting this holistic approach, colleges and instructors can effectively address the diverse needs of students in developmental mathematics education, ultimately empowering them to succeed in their academic pursuits and beyond.

Conclusion

In conclusion, the adoption of computerized adaptive learning platforms into developmental mathematics coursework poses both opportunities and challenges for students' learning experiences. While these platforms offer personalized learning experiences and real-time progress tracking, concerns arise regarding their effectiveness, especially for students who may lack study skills or struggle with engagement. The literature emphasizes the importance of employing a variety of teaching methods and resources to enhance student engagement and improve learning outcomes in mathematics (Lugosi & Uribe, 2020). Studies also indicate that collaborative learning and peer-to-peer interactions play crucial roles in promoting student engagement, motivation, and confidence in mathematical abilities (Sofroniou & Poutos, 2016; Zhang, 2024). Moreover, incorporating multiple modalities in teaching, such as visual aids and real-world examples, caters to diverse learning styles and enhances student understanding (Berthold & Renkl, 2009; Hargerty et al., 2010; Kumar, 2017).

Furthermore, studies suggests that a blended approach combining online platforms with face-to-face instruction yields better student outcomes than either approach alone. Examples like the Black Hills State University's redesign of the College Algebra course underscore the potential of integrating technology and collaborative learning methods to enhance student performance and engagement (Hagerty et al., 2010). ACC's seamless integration of computerized platforms like ALEKS into mathematics classes, emphasizing their potential to enhance student learning while still fostering student-teacher and student-tutor interaction, especially for underrepresented male populations (Lollar & Pipper, 2023). Those examples emphasize the notion that technology should enhance, not replace, face-to-face instruction and interaction. Overall, while computerized adaptive learning environments hold promise for improving student outcomes in developmental mathematics, careful implementation alongside traditional teaching methods is crucial to ensure a well-rounded and effective learning experience for all students.

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