An Alternative Model of Online Mathematics Instruction to Promote Student Support

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Abstract

Limitations of classroom space, time, economics, and a growing global village turn many adults to electronic-based resources for learning. In this paper, we analyze models of online learning, particularly for adults learning mathematics as a part of a degree or certificate program. Several decades of research point to benefits of online learning, but also a number of concerns and limitations based on test performance, student retention, and the limitations derived from indirect human contact. As a preliminary study, we describe the structure of online mathematics courses at a four-year degree granting institution that has taken an approach unlike a traditional classroom. Instead of one teacher interacting with a group of students with homework, quizzes, lecture, and exams, the alternative model includes many faculty that support a student as they progress through self-paced instruction, competency-based learning, and criterion-referenced assessment. We detail the software and hardware used by the faculty, and a demonstration of how the technology used allows for fully online instruction, mentoring, advising, and assessing. Surprisingly, this model is more cost-effective for both the institution and its students. We conclude with recommendations for best practices in designing support for adults taking online mathematics courses.

1. Introduction

Historically, distance learning has been around for several centuries, but perhaps not widely available [9]. Online courses using the internet and digitally produced learning materials have become widely available in the past few decades; including Massive Open Online Courses (MOOCs), flipped classrooms, and now degrees and certificates offered entirely online. Even so, a large number of stakeholders including teachers, administrators, students, and businesses are reluctant to completely replace face-to-face instruction with online learning [15]. One concern is that interacting with a computer rather than a person may be dehumanizing [12]. Other concerns include the potential for cheating, the lack of student-to-student interaction, and the possibility that the technology does not perform correctly [6]. Learning mathematics may be particularly difficult for many students to learn without the resources they may have access to at a physical school. Other complaints about the limitations of online courses may be the result of some online courses being designed to function exactly like a traditional classroom, when the learning perhaps should take more advantage of the benefits of technology [1]. In this paper, we review some of the limitations of online learning addressed by research as well as frameworks for how to design online courses to maximize learning potential for students. In particular, we describe a model for an online mathematics course offered by a university that offers degrees 100% online. The model is significantly different from a traditional classroom in the types of support and technology tools students can access. We conclude with suggestions on how to measure the effectiveness of online mathematics courses, and a summary of the affordances and constraints of this particular model.

2. Literature review of online courses

There are many reasons why students, educators, businesses, parents, and administrators might consider online instruction, but most of these reasons may be summarized as a matter of time, economics, and/or convenience [2, 12]. From a student perspective, online courses make it possible to increase expertise without the expense of moving away from home, paying international tuition rates, and having to worry about finding work near the school so that they can pay for school. Educators may find online teaching convenient because they can prepare materials from an office or at home, they won't have to make paper copies or use chalk, and they may be able to use technology to grade homework and exams. Administrators are interested in saving classroom space, furniture, and liability by having students (and perhaps faculty) stay home. Many administrators also consider if online courses will allow enrollment to increase far beyond the physical size of a classroom when a classroom is no longer used [2, 9].

For researchers who try to measure the benefits of online instruction, data is collected to analyze how adults learn and which adults are predicted to succeed in online courses. From an access perspective, online courses enable a very broad population of adults to increase their education who would not otherwise be able to attend a physical school [2, 12, 15]. This could be because of their job, child care, a remote location, a physical impairment, or a variety of other reasons. If a student taking online courses would otherwise not be able to attend school at all, then online instruction provides perhaps their only means of increasing their education, skill level, and career opportunities. However, research indicates that not all adults will succeed with online courses [10, 12], and perhaps institutions should initiate procedures as a part of the admission process to help determine if applicants are a good fit for the coursework. In particular, students who exhibit evidence of self-directed learning are predicted to learn more and complete their degree in the independent (and sometimes solitary) environment of online courses [1]. Other benefits include the fact that students taking online courses generally need very little hardware (a computer with internet access, a microphone, and speakers are easily obtained), and that they need very little technical knowledge and skill to access the course.

Many colleges and universities over the past few decades have added online course offerings as a way of marketing additional course options to prospective students. Surveys indicate that most of these courses are designed to imitate a traditional face-to-face class [15]. In other words, the course consists of a single teacher who delivers content such as homework, quizzes, exams, grades, and lectures, which may be in the form of live or recorded webinars, videos, PowerPoint presentations, or a combination. However, faculty and student satisfaction with these courses has been lower [14], and some research indicates that online and face-to-face courses should neither mimic each other nor should they be compared against one another for quality and learning [3, 6].

One issue common to much of the research in online learning are blog posts, where students are supposed to post comments and questions about their learning online as a form of academic discourse. Both students and faculty complain that this activity does not measure complex thinking or learning, because the posts are forced (as a part of a grade requirement), the content remains at a low level, and that this form of communication does not lead to new ideas or thinking [6, 15]. For a mathematics course, it is difficult to imagine how blog posts would help students to navigate through conceptual understanding, procedural fluency, and problem solving in mathematics.

Amongst other reasons, mathematics as a content is less likely to be easily discussed with the language tools available on a standard keyboard. At the time of this writing, almost all research found on online mathematics courses pertained to motivation, student self-efficacy, and comparisons to a nearly-identical face-to-face course [15].

Perhaps the second most common models of online courses are the MOOCs. Massive Open Online Courses (MOOCs) are typically offered for free and are open to thousands of students at one time, but fewer than 10% actually complete the course [9]. MOOCs are not courses that are part of a degree program. Typically course content is pre-recorded and loaded, and any grading is done by the computer or by the other students taking the course. These courses generally cannot be used for credit towards a degree but rather help individuals build their resumes and provide workshop information in their field of interest. One of the first MOOCs was *Introduction to Mathematical Thinking* offered by Dr. Keith Devlin of Stanford University since 2012 [9].

Much of the existing research on online teaching and learning is not content specific, and most focuses on student satisfaction [1, 15]. In particular, students have a tendency to be dissatisfied with the amount of feedback they receive, the lack of peers, and periodic failures of the technology (e.g., when the internet is down or when the website itself is not functioning). When a computer scores quizzes, exams, and homework, the primary format of that online work is multiple choice questions. Since the computer cannot evaluate how the student arrived at a response, the student will not know if their thinking was correct or not [12]. Because mathematics includes many symbols, figures, and graphs, it is difficult for students to articulate questions and answers using a keyboard and an online platform [14]. This is especially true if they do not possess the academic language to be able to explain what it is they do not understand. Online course concerns from teachers include many studies that show students do not engage in discourse that includes synthesis, application, or complex thinking. Teachers are also concerned with cheating, especially on exams, when they do not physically see or know their students.

Although content-specific online mathematics course research is scant at this time, many publications have reviewed research on best practices for online learning with adults. Below is a list of common recommendations for online course instruction and design:

-institutions need to ascertain good online learning candidates as part of admission [10, 15]
-there should be a clear and consistent course structure [4, 6]
-the instructor should interact frequently and constructively [2, 4, 6]
-it includes a valued and dynamic discourse [6, 15]
-learner-learner interaction is critical, including cooperative and project-based [1, 2, 4, 13]
-feedback should be constructive, specific, clear, and accurate [4, 6]
-course includes options; it is self-paced and personalized [4, 6]
-grades are for mastery (criterion referenced) rather than norm-referenced [1, 6]
-the leader emphasizes individual student efficacy and is more of a mentor, coordinator, or facilitator than a primary conveyor of knowledge [2, 4, 6, 15]

In the next section, we describe a model for online learning that is used at an institution with 100% of course offerings and degrees as online distance education. Instead of a *single* teacher supporting the learning of a *group* as in a traditional face-to-face class, courses include a group of supporting faculty who work together for an individual student's success. As such, the concept of a "class" with "students" and a "teacher" does not exist at this school. Courses are entirely self-paced, criterion referenced, and measure competency-based learning.

3. A model of student support for online learning

What follows is a description of an online learning model that is competency based, student-centered, and goes against many of the paradigms associated with traditional brick-and-mortar institutions as well as most other online models of distance learning. In this competency based program, students can accelerate through their studies or choose a slower pace as long as they complete 12 credit units within a 6-month term beginning and ending according to the student's choice. This configuration is equivalent to a traditional US semester minimum full time load but with a longer period of time than typical US semesters, trimesters, and other versions of academic terms. In other words, a student can begin a term on the first day of any month and the end of term is six months later. If students complete these credit units before their term ends, they may work on additional courses for *no extra cost*. In this competency based model, students are not required to engage in the learning resources before they pass an objective assessment and/or performance assessments. Essentially, if students can prove their competency in a course by passing a final exam, they pass the course. Students are not required to log engagement in a digital learning resource and there are no classes to attend in the traditional sense. Live webinars and 1-to-1 meetings with course content faculty are available to students but not required.

This institution's approach to assessment and evaluation integrity is shown by its unique organizational structure. Evaluation and assessment faculty do not interact with students or mentors. Student interaction with faculty is confined to content specialists who hold PhDs and other staff who facilitate academic advising and other university services. Members of evaluation faculty are subject matter experts with expertise in assessment. Evaluation faculty create assessments, score student tasks that cannot be evaluated by computer software, study assessment data, and engage in research to constantly refine the assessments and evaluation criteria to meet accreditation and compliance standards in all 50 US states. This organizational model was designed with the assumption that releasing instructional faculty from scoring student work or creating curriculum would lead to a greater focus on helping students learn through one-to-one and one-to-many interactions.

Upon acceptance to the university, each student is assigned to a Student Mentor (SM) for the duration of their degree program. The SMs assist with planning the degree program, provide guidance navigating university resources, and maintain weekly communication with their assigned students via email and phone calls. During phone meetings with students, SMs can use a computer screen-sharing application to help students find learning resources.

When students engage in a course, they are assigned a Course Mentor (CM) who is a subject matter expert with a PhD and provides support via email and phone conversations. For interactions with mathematics CMs, students typically use screen sharing to view the CM screen while they talk on the phone. CMs also use Adobe rooms for these meetings, especially when a student cannot rely on their phone but have a stable internet connection. Adobe rooms allow for voice interactions as well as screen sharing. A key feature of these meetings is that CMs can display mathematics problems and write on the screen with a tablet. One major benefit of tablet technology is that it allows students to focus on the instructional dialogue knowing that the screen writing, calculations, and diagrams can be saved and sent to them in an electronic document [14]. These one-to-one interactions facilitate student-centered individualized instruction and support self-directed learning. Usually students formulate their own agenda for meetings with CMs and refer to specific concepts and mathematics problems from the course content. Students are in control of scheduling appointments with CMs as needed. There are no constraints on how often students can meet with their assigned CM or even other CMs from the same course. Figure 3.1 summarizes student interactions with human and electronic resources available as part of the course.

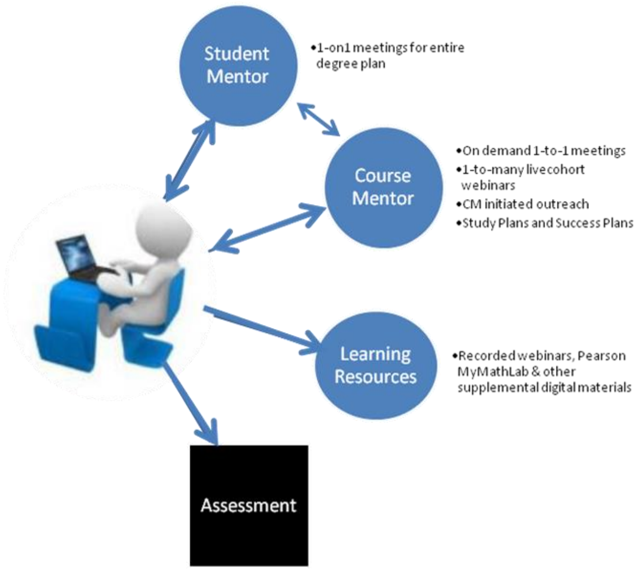

Figure 3.1 Student interactions while progressing through online mathematics course

CMs also lead live webinars in their Adobe rooms covering course material where participants may or not be from their assigned caseload of students. Webinar topics include sessions focused on individual course content units such as linear equations, graphing, operations with integers, accelerated whole course review sessions, mathematical study strategies, and even how to cope with mathematics anxiety. In these webinars, students participate in a live chat room while the CM leads them through interactive presentations, displaying mathematics problems, solving them in real time, and frequently asking students to respond to questions in the chat room while students are also free to ask questions or interact with other students. Many of these webinars are recorded and accessible to students at all times.

Students in mathematics classes also have access to a variety of online resources. They receive an account with Pearson's MyMathLab which provides them with a large number of mathematics problems to practice with. Mathematics content is organized in discrete units associated with various sub-topics. Each unit is designed for students to progress through a pre-test, homework problems, and post-test to provide, respectively, a measure of prior knowledge, practice, and objective assessment. Scores and correct answers are provided instantly but unlike most other universities using this resource, this university does not use these score reports to calculate a "grade". The guiding principle of competency-based learning is that students should have a space to learn from their mistakes free from penalty. Students are encouraged to learn from errors, to diagnose their own mistakes, and to persist in spite of error by making them feel "safe" to do so [13]. It is important to note that although many educational institutions use the scores generated in this technology to calculate students' grades, this may be unethical because it is not possible to verify that the student who registered for the course is the same person who completed this online work. With this thought in mind, we now describe how this university maintains assessment and evaluation integrity.

Mathematics students pass a course when they have successfully completed an objective assessment and performance assessments developed and scored by the university assessment and evaluation team. Table 3.1 is a sample of course objectives for one online mathematics course offered by this institution. Students and CMs are encouraged to take a formative pre-assessment, created and scored by the university assessment team. These pre-assessments instantly generate a coaching report for the students and send digital reports to CMs who formulate a Study Plan for the students based on the pre-assessment scores. Students are able to view the questions in a format that shows what they answered as well as the correct answers. These pre-assessments provide incentive for students to schedule appointments with their CMs to foster a discussion about specific mathematical questions and collaborate on next steps for study.

For online objective assessments, students are proctored remotely by an internet assessment proctoring service and are required to be alone in a closed room with their computer and only a whiteboard, marker, and non-programmable calculator not capable of internet access. This internet proctoring service establishes the student's identity and maintains webcam surveillance of the student throughout the test. In other words, a proctor is a person who watches the student via live web camera for the duration of the assessment.

Objective assessments are most often a mix of multiple choice and constructed response items that are computer scored. Performance assessments are essentially extended homework assignments and are more common for advanced mathematics classes. Students use a variety of technologies to complete these tasks. For example, a Calculus II performance assessment requires a great deal of mathematical symbols and writing in a format that is still difficult to accomplish without freehand writing on paper. Students can fulfill this task with various combinations of available digital technologies. For example, students can write on paper and capture a digital image for submission if they do not have access to a tablet or if the nature of the task is too difficult to transcribe with current digital mathematical text software. These tasks are scored by faculty in the evaluation branch of the university and do not interact with students or directly with CMs or SMs. The rationale behind this design is to place students in a position to take responsibility for demonstrating their learning to a third party anonymous expert, allowing CMs to focus on helping students learn course content from a greater position of objectivity. In this model, the CM is something different than the "instructor". Conversations between CMs and students cannot devolve into antagonistic exchanges where the student asks "Why did you mark me wrong?" because the CM is not the evaluator of the assessment and does not assign scores.

Table 3.1 Content objectives for Mathematics for Elementary Educators I Course

·**Problem Solving** The graduate applies problem-solving strategies and analyzes patterns to solve application problems. ·**Basic Set Theory** The graduate applies basic set concepts, operations on sets, and Venn diagrams to solve problems. ·**Whole Numbers** The graduate connects a variety of models and algorithms to the properties and operations of whole numbers. ·**Number Theory** The graduate applies concepts and procedures related to the composition of numbers to find greatest common factors and least common multiples. ·**Integers** The graduate applies the definitions and properties of integers and their operations to solve problems.

In some mathematics courses, such as a mathematics content course for elementary educators, the only requirement for passing the course is to successfully complete the online proctored objective assessment by matching or exceeding the cut score. If students do not pass, they may try again. There is a limit to the number of times a student can take an assessment and there are protocols that require involvement by more faculty members after the second unsuccessful attempt. If a student is not able to pass an objective assessment after four or five attempts, the student receives extra counseling and may not be allowed to continue in the degree program.

Once an objective assessment is completed but not passed, the student's assigned CM can analyze an electronic score report mapped to mathematical content standards (see Table 3.1). The CM and student cannot view the actual scored test items. This pedagogical practice prevents "teaching to the test" and allows the CM and student to focus on the objectives and mathematical concepts rather than the individual test items.

Next, the CM meets with the student and collaborates on a plan for study. This plan of study may include recommendations for engaging with specific online learning resources such as live or recorded webinars and Pearson's MyMathLab [14] as well as more meetings with the CM to review progress and provide instruction specific to the student's needs. For example, the CM may observe that the student did not score well on test items covering Set Theory. Prior to meeting with the student, a CM would access the student's account in MyMathLab, review the student's work and analyze their correct and incorrect responses in the learning resource in order to formulate an instructional plan unique to the student. If the student has not engaged with the online resource, the CM typically recommends work in specific units or possibly all of them, depending on their judgment of the student's content knowledge. These 1-to-1 interactions are key to this university's learning model, relying heavily on CMs' expertise for facilitating student learning. The CM's primary function is to use technology for enhancing interaction with students in a distance learning environment and to provide mentoring on how to effectively use available digital resources in this self-directed, student-centered learning institution.

Table 3.2 summarizes the types of digital resources used for specific activities that support learning and collaboration for an online mathematics course at this university. It is important to note that students are required to own their own internet-capable computer and a phone, but all other software resources are provided at no extra cost to the students.

Table 3.2 Summary of digital resources used in supporting student success

Digital Resource	Activity
Screen sharing software	1-to-1 instruction between student and faculty
Webinar/conferencing software	1-to-1 and 1-to-many instruction for meetings with students and faculty and between faculty
Pearson MyMathLab [14]	Student resource for mathematical practice also accessible by faculty
Video recording/viewing software	Faculty created instructional resources viewed by students
VOIP phone	Faculty tool for meeting with students
Computer with internet access equipped with webcam, microphone, and speakers	Used by faculty and students for all interactions

Finally, although Mathematics for Elementary Educators I does not have a formal syllabus, students are provided with a pacing guide, along with repeated communications that individual students may work at their own pace, either faster or slower as needed to master the material. A sample pacing guide is provided in Table 3.3.

Table 3.3 Pacing Guide for Mathematics for Elementary Educators I

Week 1

- Unit 1 Addition and Subtraction of Whole Numbers
- Unit 2 Multiplication and Division of Whole Numbers

Week 2

- Unit 3 Mental Math and Estimation
- Unit 4 Divisibility and Primes and Composites
- Unit 5 Greatest Common Divisor and Least Common Multiple

Week 3

- Unit 6 Integer Addition and Subtraction
- Unit 7 Integer Multiplication and Division

Week 4

- Unit 8 Basic Set Theory
- Unit 9 Problem Solving

Week 5/6

- Assessment

4. Constraints and next steps

In comparing the list of best practices with the model described, we find that many of these practices are an integral part of online instruction at this university. For example, we know that the institution has a comprehensive procedure for determining if a prospective student will succeed with self-directed learning. We also know that Course Mentors and Student Mentors contact each student frequently through email, phone, and web conversations about their progress, next steps, and resources suggested for their improvement. Although MyMathLab and the final assessment do not provide specific feedback for students on their mathematics, online meetings with CMs do provide feedback and mentoring that is constructive, personalized, and accurate. Courses are graded only on a pass/fail basis, and students may continue to try to pass on their own timeline.

Further research is necessary to quantify and qualify the effectiveness of this university's online mathematics courses. Specifically, we are interested in data about students and instructors with respect to their satisfaction, critiques, and successes with this pedagogical model. In the meantime, we remain optimistic about the positive effects of this unique model judging from [15] which shows that in the US:

> Nearly three-quarters of [this university's] graduates (73%) strongly agree that their education was worth the cost. Among [this university's] comparison group peers, public universities rank second in perceived value to their graduates, though they trail [this university] by more than 30 percentage points (p.4).

What is starkly missing from this model are student-student interactions and productive, two-way complex academic discourse. We recognize the large body of educational literature pointing to the critical importance of student development of content-specific academic language as well as the social emotional and self-efficacy gains from being a member of a cohort of students that have similar academic and career goals. Because a "semester" for an individual student begins on a date of their own choosing, there isn't a clear way to identify a class of students, a cohort, or even a group of students that might be in the same geographic area and might at some point become professionals in the same city. As a future step, we are interested in measuring how this shortcoming may affect the performance of graduates, including their ability to obtain employment and their satisfaction with their employment and education. We would also like to explore how to make student discourse and academic language a critical component of this model.

From the literature, we find a lack of research specifically about the best practices of teaching and learning mathematics in online courses. Although [5] and [13] provide comprehensive reviews of the state of online education in terms of pedagogical practice and course structure, we were not able to find answers to our specific questions. From [15], we agree that two important and still relatively unaddressed questions are "What constitutes teaching in online [mathematics] classes?", and "What difference does the nature of [mathematics] make in online classes?" We agree from the literature that online courses should not be compared to face-to-face courses for knowledge on how instruction should be designed and what resources and faculty should provide to students. Instead, institutions offering some or all mathematics courses online should be transparent about their frameworks so that researchers may begin the work of a more logical comparison. We also recognize that software and hardware offerings and capabilities are changing at an extremely rapid pace, so that by the time a study reaches publication in a journal, some of the information may be obsolete.

5. Conclusion

In this paper, we recognize the growing attractiveness of online courses for their efficiency and convenience, particularly for adult learners and institutions who serve them. Current research shows that many online courses are designed to imitate face-to-face courses, and further that this model may not be the best way to take advantage of what technology can offer to enhance learning. As with face-to-face mathematics courses, online instructors struggle to design tasks that lead to complex student thinking, student academic discourse, and ultimately, student success both in the classroom and beyond. We describe a model used by an all-online university that views a single student (as opposed to a class) as a unit of instruction that is supported by technology, software, and a number of education professionals. While this design achieves many of the suggestions for research on best practices for online learning, it does not encourage student-to-student discourse, collaboration, or direct contact of any kind. We also note that since students pay a single fee for six months of coursework, the model is efficient and cost-effective for the students, the instructors, and ultimately the institution. We conclude with a call for researchers of mathematics, technology, and online instruction to analyze models of best online mathematics learning and teaching, and to add to the still small body of research that tries to measure this important topic.

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