Friend or Foe: The Dangers of Depending on Online Platforms for Conceptual Understanding

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Abstract

There is no shortage of online platforms used to teach Mathematics. Top textbook publishers are now including the platforms in combination with a printed or e-textbooks, and are marketing the platforms as a substantially helpful tool for both students and instructors. Having used many of those platforms over the past 8 years, I give an overview of some of their strengths and weaknesses overall, and use data collected from various platforms that suggests that the benefit of these platforms for students may simply be acquiring procedural competence only. My hypothesis is that students' overreliance on the help tools of the platforms, along with the large number of procedurally-oriented questions make these platforms useful for acquiring procedures, but not necessarily for understanding concepts. I propose modifying the reliance on a textbook platform to the creation of stand-alone courses that involve the use of interactive videos. The features for this approach would enable students to further enhance their conceptual understanding of the content, all while providing them with the interactive engagement needed to understand content. I contend that a hybrid courses that uses interactive videos and smartphone apps would be more effective in delivering and ensuring a better and more rewarding educational experience for the students

INTRODUCTION

The interest in the proper incorporation and use of technology in the classroom stems from the vast array of possibilities that technological tools seem to offer. Technology enables the exploitation of dynamic media like audio, video, and interactive software, allows students to collaborate in ways that were previously impossible, and provides tools to increase teacher productivity from lesson planning to record keeping. There are several pedagogical reasons given for the benefits of using technology in the classroom such as students' engagement, interactivity, and students' empowerment. Students using technology become active participants in the learning process instead of passive listeners. One-to-one technology enables the access, manipulation, presentation of, and much more importantly, the creation of, multimedia rich descriptions and analyses. "Technology can transform students from passive recipients of the teacher's knowledge to autonomous knowledge-constructors, and can provide a pathway for students to work at higher levels of generalization and abstraction, enhancing their understanding of concepts, and enabling them to make and test conjectures." [1] From a teacher's perspective, the advent of electronic technology can allow teachers and curriculum designers to focus more on mathematical ideas and devote less classroom time to the mastery of mechanical and computational skills.

Among the technological tools that gained popularity over the last decade are computer-aided assessment systems, most importantly the online software platforms that allow students to review topics and concepts, submit assignments, and take quizzes and tests. Various textbook publishers have created their own online platforms to go along with their own textbooks, while others partnered with existing platforms in an effort to add a technological component to their course delivery models. This paper discusses the main features of a number of leading online platforms, and highlights a number of potential add-ons that can make the platform geared to promoting students' conceptual understanding, empowering the instructor with a tool that serves more than just a homework collector.

MyMathLab

Since 2001, Pearson Education has been promoting and bundling online homework and testing platform called "Math XL". MathXL was marketed as "a powerful online homework, tutorial, and assessment system that accompanies Pearson Education's textbooks in mathematics or statistics." (Math XL.com). The developers of the platform claimed that it engages students in active learning. Pearson describes it as adaptable to each student's learning style, and states that it presents instructors with the possibility of customizing it to better meet their students' needs, and to help them "be the best they can possibly be". Teachers or professors can select from the program's bank of free-response exercises, edit them, or add their own questions, and have students complete them in a lab setting as classwork or quizzes, or outside of class as homework.

In 2012, Pearson introduced a product that was intended to phase out MathXL, a more advanced platform called MyMathLab. This was in line with a surge in adaptive learning, a technique that recommends to students what math exercises they should tackle, based on the content they've already mastered and the level of difficulty and style that seems to fit them best. The "Study Plan" feature analyzes students' responses per topic or section, and provides them with additional questions on the topics or areas that they underperformed in. The aim of this feature is to help students focus on their weaknesses while reviewing or practicing. As for instructors, MyMathLab also provides them with the possibility of creating homework assignments from previously uploaded exercises, track their students' results, copy a previous course, create custom exercises, and upload media assignments. MyMathLab also contains an e-book version of the student's textbook, video lectures, and animations, and gives students 24/7 access to Pearson tutors online. It is worth noting that Pearson Education highlights the platform's capacity to provide instant feedback and variation as a path to "mastery", stating that "the exercises in MyMathLab reflect the approach and learning style of the textbook or e-text, and regenerate algorithmically to give you unlimited opportunity for practice and mastery." [2]

Most exercises include learning aids, such as guided solutions, sample problems, and extra help as you're working through them, and they offer helpful feedback when you enter incorrect answers. A variety of multimedia resources are also available in the homework and study plan exercises. Instructors can link to the eBook, video clips, and animations to improve your understanding of key concepts. Videos are captioned in English, and several courses are also captioned in Spanish.

WILEY PLUS

Described as "an online teaching and learning solution", Wiley Plus is the platform associated with the John Wiley and Sons Inc., publishers of academic textbooks in business, computer science, engineering, mathematics, and statistics. The software holds a number of similarities to the previously discussed platforms, in the sense that it offers students the possibility to submit homework assignments, practice exercises, and take online quizzes and tests. The Wiley Plus team claims that the benefits of using the platform goes beyond just collecting homework, since it "builds students' confidence because it takes the guesswork out of studying by providing a clear roadmap; what to do, how to do it, and if they did it right."[3]
The focal points of Wiley Plus's success are (according to the platform's developers) the clarity of design (Students and instructors are provided with simple instructions on getting started, system requirements, and an introduction to the course), the clarity of learning objectives, as they "assist students in focusing their effort in the course", the multiple assessment strategies that "measure effective learning, evaluate student progress, and are designed to support the learning process", the resources and materials that are "comprehensive and contribute to the achievement of the stated learning objectives", and a comprehensive set of support resources is available to both students and instructors." [3] Wiley Plus developers also claim that meaningful interaction is employed to motivate and engage students.

Students who use the WileyPlus platform can submit assignments online (up to the number of times set by the instructor), get instantaneous feedback on the problems attempted, access the textbook fully, and check the full solutions of all the textbook problems in detail. Students also can use built-in help tools while attempting a problem, such as "Hint", which obviously provides a hint on the problem in question, and "Textbook", which takes them immediately to the textbook page/section that relates to the problem they are attempting to solve. Instructors can set up assignments from a preset pool of questions, or create their own problems and assign them to their students.

COMMON FEATURES

Though each of the software platforms aforementioned include one or more feature that is not available in the other, it is quite clear that they both share a number of common features. Students can use either one of the two platforms to submit an assignment or a quiz (often with the possibility of multiple submissions), get instantaneous feedback on their answers, access a large database of additional problems, and use various online help tools that range from watching videos, to reading a solved exercise, to asking for clarification from the course's instructor. Both platforms discussed in this paper provide the instructor with the possibility of using a built-in question bank for homework, quizzes, and tests, or creating their own questions database. Also, all of them give the instructor the right to set the number of attempts allowed per question or assignment, and amend grades in the gradebook if needed.

DRAWBACKS and ISSUES TO CONSIDER

NCTM *Principles to Actions* (2014) highlighted, addressed, and documented a range of troubling and unproductive realities that exist in too many classrooms, schools, and districts, namely the fact that "too much focus is on learning procedures without any connection to meaning, understanding, or the applications that require these procedures." (NCTM PtA, 2014) [4]. There is a compelling case for overreliance on technology "for the sake of technology" instead of tying the use of the technological tool to conceptual understanding of the content.

Another critical issue in determining the effectiveness of the platforms' use is the kind of knowledge a course instructor is trying to target. In general, the mathematics education community recognizes two major types of knowledge (although intricately related and linked): Conceptual and Procedural Knowledge. A 1986 book by Hiebert and Lefèvre, "Conceptual and Procedural Knowledge: The Case of Mathematics"[5], was one of the earliest and most recognized attempts of looking at the relationships between conceptual and procedural knowledge. Although the two types of knowledge were still treated as distinct, they were linked in mutually beneficent ways. In the chapter, "Conceptual Knowledge as a Foundation for Procedural Knowledge," Carpenter characterized conceptual knowledge as knowledge that "involves a rich network of relationships between pieces of information, which permits flexibility in accessing and using information" (1986, p. 113). Hiebert & LeFevre also defined conceptual knowledge as "knowledge that is rich in relationships" (1986, p. 3), and thought of it as a web of knowledge in which individual facts and propositions are linked. Hiebert & Lefevre argued that "a unit of conceptual knowledge cannot be an isolated piece of information" (1986, p. 4). Instead, it is a part of conceptual knowledge only if the holder recognizes its relationship to other pieces of information" (1986, p. 4). More up-to-date definitions of conceptual knowledge bear a lot of resemblance to Hiebert & Lefevre's, like Rittle-Johnson & Alibali (1999), who define it as "explicit or implicit understanding of the principles that govern a domain and of the interrelations between pieces of knowledge in a domain" (p. 175).

As for procedural knowledge, Hiebert and Lefevre (1986) defined it as knowledge of the symbol representation system (the formal language of mathematics), and of the rules, algorithms, or procedures for completing mathematical tasks. Knowledge of the symbol representation system encompasses familiarity with the symbols as well as awareness of syntactic rules (that $a+b=c$ is a syntactically valid statement, while $a+=bc$ is not). In the advanced levels, this knowledge includes awareness of syntactic configuration of formal proofs without necessarily knowing the content of the proof, just the validity of its structure. Knowledge of algorithms means the knowledge of the rules or procedures used to solve mathematical tasks. Algorithms are perceived as step-by-step instructions that are executed in a predetermined sequence and prescribe how to complete tasks. These procedures move in a sequential order from the given to the answer. Rittle-Johnson & Alibali (1999) produced a concise definition when they defined procedural knowledge as "action sequences for solving problems" (p. 175). Star (2005, 2013) deviates from this dichotomy, as he argues that the definitions of conceptual and procedural knowledge (as proposed by Hiebert & Lefevre) represent "a critical departure from psychological views of concepts and procedures"[7] (p. 407), since these definitions only refer to the "quality" of the knowledge type. For instance, the term "concept" in itself implies connected knowledge, but Star points out that the "connections inherent in a concept may be only limited and superficial, or they may be extensive and deep" (2005, p. 407). He argues against the perceived view within the mathematical community, where "it is relatively common in mathematics education research to see conceptual knowledge defined and operationalized as a quality." (2013, p. 179).

IMPLEMENTATION

The platforms highlighted above have been used in teaching introductory undergraduate mathematics courses (namely precalculus and mathematics with business applications) at the American University in Dubai for several years, and the most common complaint that was instructors shared (regardless of the level of the course and the target audience) was the substantial discrepancy between the students' performance on the platform assignments and the in-class assessments (formative assessments like worksheets, as well as summative assessments like quizzes and tests). In fact, during the 2017-2018 academic year, a simple comparison test was conducted on 62 MyMathLab and 57 WileyPlus users, with the parameters being assignments scores vs. in-class scores (Quizzes and Tests). The below results were found:

- Homework Average for MyMathLab: 82.47% ($\sigma = 2.21$)
- In-Class Average for MyMathLab: 66.36% ($\sigma = 6.41$)
- Homework Average for WileyPlus:73.1% ($\sigma = 2.36$)
- In-Class Average for WileyPlus: 59.9% ($\sigma = 5.94$)

It is worth noting that many problems in the quizzes were drawn from the platform questions or similar to them. So, several interpretations can be offered for the significant differences observed, namely overreliance on help tools, test anxiety, the difference in the quality of questions between in-class assessments and the platform, or under-preparation for tests.

An in-depth look at one of the potential reasons behind this discrepancy resulted in classifying (for the most part) the built-in problems (within the platform) as aimed to a large extent at students' skill building, since many of the exercises are very similar to the examples given in class and online. Since homework can be submitted and re-submitted until students "get it right," and help tools walk the students through step-by-step procedures, many students seemed to develop an overreliance on help tools to master procedures. While skill building is an important objective in any Math course, instruction that is geared towards building skills ***only*** often leaves students as procedure mimickers rather than conceptually competent learners. If instructors using the online platforms aim at promoting students' higher order thinking skills and enhancing conceptual understanding, then settling for the current platform content and format may not be enough, thus they (instructors) must use creative strategies to challenge students' thinking and engage them with problems that go beyond merely procedural competence. The following add-ons have been used by the author and proved to be efficient in engaging students in more than just manipulating symbols. It is important to note that these are suggested enhancements that may or may not work depending on the students' level and willingness to engage, as well as the type of the course offered, as a developmental course may require a different set of teaching tools and methods that substantially differ from a first course in Calculus for engineering students.

Proposed Adjustments and Add-Ons

For a platform to enhance both conceptual knowledge and procedural competence, instructors can use some of their features to make the learning experience geared towards more than just symbolic manipulation and procedure repetition. Instructors can create their own custom questions and insert them in assignments and quizzes. This enables the instructor to control the content, the level of difficulty, and to gear the question towards more than just simple calculations. For instance, in a custom question on MyMathLab, the instructor asked the students to study the relationship between two quantities and then determine what kind of function would represent this relationship, before asking for a numerical application. This kind of question format forces the students to make connections with previously discussed topics and allows the instructor to investigate whether the students can make those connections successfully. Other possible benefits include making familiar with the instructor's questioning style, as it might differ from the types of questions found in the questions' database.

In addition, most of the videos found on the aforementioned platforms detail the steps needed to solve a problem, or attempt to explain a certain procedure. In fact, this trend appears in many instructional videos, be it a video accompanying a software platform or simply an online video on a video sharing website (like YouTube). But this doesn't have to be the case for the instructors who seek more than teaching students how to duplicate a procedure. With the possibility of making and adding one's own videos, instructors can use this feature to upload explanation of lessons, questions and problems for the students to do on their own (MyMathLab calls this a media assignment), and detailed explanation of the responses to the questions.

Several advantages can be found for the video tools, such as controlling content, providing students with explanations and hints, and the access students can have to their instructor's image and voice outside the classroom (a familiarity component). But most importantly, instructors can design the videos so that they can have an interactive dimension. In a series that can be found on YouTube [7], the instructor provides the students with some background information, then proceeds to ask the students to answer a series of questions and justify their answers. The instructor recommends that students pause the video, answer the question, then play the video to check whether their answer matches the correct answer. This enables the students to engage with the content and takes away the passivity of simply watching a video to see "how" a problem is solved. This approach appears to sit well with the students, as they can tell whether they got a concept or not simply by checking the accuracy of their responses in private, without worrying about responding in front of their peers in class.

To test the capability of the interactive videos approach, a group of 25 Pre-Calculus students were assigned to watch a series of videos made available on Blackboard prior to class attendance. The students were expected to lead the classroom discussion in the next session (after watching the videos), and then do an in-class activity before working on the platform-based homework assignment next. This went on for two chapters, and lasted about 5 weeks, at the end of which a survey was conducted. 17 out of 25 students answered with "strongly agree or agree" to the questions "did you find this approach useful/beneficial to you?", while 6 were neutral and 2 disagreed. It is quite clear that while a full-fledged research was not conducted, it is a good indicator that adding such a component to the courses that are partially (or fully) based on an online platform can produce significant improvement on students' understanding of content geared towards conceptual understanding.

CONCLUSION

Online software platforms are gaining rising popularity due to the rapid increase in the interest usage in educational settings. It is more common nowadays to collect homework online that to spend hours manually grading lengthy homework assignments. The many features of online platforms make them useful and convenient for both students and instructors. However, the "hidden" potential of such platforms lies in their ability to promote students' conceptual knowledge all while enhancing their computational skills. To do so, instructors can use the features of the platform to create customized questions tailor-made to fit his/her students' needs, and upload instructional videos with an interactive dimension, where students can respond to various questions to gradually understand and apply the underlying concepts.

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