The Use of Technology in Teaching Mathematics

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Abstract: Technology provides instant information. Appropriate use of diverse types of technology is important in the classroom including a virtual classroom, and integration of technology will enhance the student learning experience. Utilizing a variety of technology will actively engage students with learning objectives, generate communications among students/instructors, spark more intellectual curiosity among students, and assist instructors to meet the unique needs of individual learners. The purpose of this paper is to determine whether technology, multimedia in this case, works to improve student performance in an in-person or an online instructional environment; to reveal the value of multimedia in online learning as perceived by the students; to provide a glimps of an innovative curriculum that will help students to become successful members of society and prepare them for a wide range of professions. Data were collected and analyzed to show that technologies, multimedia in this case, have made a big difference on student performance in an online instructional environment.

Keywords: Technology, Mathematics learning, Online learning

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Introduction

Technology and multimedia can contribute positively to student performance in an in-person or an online instructional environment. Multimedia is the combination of various digital media types, such as text, graphics, audio, video, and animation, into an integrated multisensory interactive application or presentation. Owing to its attributes (i.e., visual, interactive, engaging, and animated), multimedia can present or represent action, objects, phenomena, or status that text alone can't or can't do as well (Hedberg, 2004; Mayer, 2002).

One of the key advantages of multimedia is its capability of demonstrating qualitative and quantitative relationships, showing changes over time and showing hidden concepts that enable students to see and hear many of the things that they can't through text reading only. With visual display of the subject being studied, the

students can process information quicker, which, consequently, may help foster their acquisition of sophisticated skills and understanding of complex concepts and procedures that may otherwise be unattainable (i.e., the skills, concepts and procedures illustrated with simply text) (Hedberg, 2004). It is believed that learners can learn more deeply, including improved performance on tests of problem-solving transfer, from well-designed multimedia messages consisting of audio, video, graphics, and animation than from more traditional modes of communication involving verbal alone (Mayer, 2003; Paivio, 1986; Clark & Paivio, 1991).

Online education continues to grow across disciplines at institutions of higher learning (Glass & Sue, 2008; Olesova et al., 2011; Wagner et al., 2011). Accompanying the popularity of online education is the use of technology in teaching and learning that is believed to be redefining how learning takes place (Brown, 2002). Along with the increasing use of iPads, tablet PCs, or smart phones, students are becoming familiar with and accustomed to listening to and watching materials which traditionally were simply read. *The Horizon Report* (Johnson et al., 2009) identifies "digital media literacy continues its rise in importance as a key skill in every discipline and profession" (Johnson et al., p. 3). A meta-study and review of literature of 51 online learning studies released by U.S. Department of Education (2009, p. ix) found that "on average, students in online learning conditions performed better than those receiving face-to-face instruction." Various factors may have contributed to the student performance of online instruction, including multimedia. Multimedia has been argued as an effective technology means to positively impact student performance in online, blended, or face-to-face classes (Astleitner & Wiesner, 2004; Paivio, 1986, Clark & Paivio, 1991; Hedberg, 2004; Mayer, 2002; Mayer, 2003; Sadaghiani, 2010).

Education enables students to acquire knowledge and skills that will help them to become successful members of society and prepare them for a wide range of professions. The inventions and implementations of new technologies have signifcant impacts on our education, and have played key roles during the COVID-19 pandemic. Modern technologies provided new learning experiences for millions of students globally during such devastating period, and motivate educators to rethink strategies and approaches to deliver course materials, to assess learning objectives, and to evaluate students' achievements. Modern technologies make it possible to create a wide spectrum of courses that would meet the increasing demand of skilled professionals in the job markets. With this goal in mind, we carefully integrate the best-known educational practices in technologies to create innovation curriculums. The use of technologies provides an engaging and cross-discipline active learning experience to inspire students from diverse backgrounds and abilities, and to assist students in acquiring the knowledge and skills necessary to compete in a global economy.

Striving to accommodate student needs and improve their performance in learning, a variety of technology and multimedia components were introduced into the lower-division mathematics classes. The types of technology include graphing calculators, and computer software packages such as mathematical. The multimedia component consisted of learning objects presented in the format of text, audio, video, and animation. This study analyzed student performance data in several lower-division mathematics courses. Specifically, the final course

grades of the students enrolled in those courses were analyzed to determine the effectiveness of the use of the technology and multimedia. Student responses to an online survey were also discussed. The purpose of this study was threefold: First, it endeavored to determine whether technology, multimedia in this case, works to improve student performance in an in-person or an online instructional environment. Second, it attempted to reveal the value of OER multimedia in online learning as perceived by the students. Third, it strived to provide a glimpse of an innovative curriculum to assist students in acquiring knowledge and skills that will help them to become successful members of society and prepare them for a wide range of professions.

Method

MA139 Applied Calculus

Attempting to measure the impact of multimedia on student performance in an online instructional environment, one set of data collected for this study was from MA139 Applied Calculus, a three-credit hour online math course offered for the first-year students of all disciplines. The objectives of this course are to introduce basic concepts of differential and integral calculus, and to present applications of calculus to problems in business, life sciences, and social sciences. Since fall of 2010, multimedia instructional materials were incorporated in this online class. In particular, different types of multimedia such as animation, audio, video, and YouTube were used to explain some difficult concepts. Group 1 data were collected from three sections without multimedia component, and Group 2 from three sections with multimedia component. All the sections were taught by the same instructor. All course assessments were developed and graded by the instructor using the same criteria and standards.

A comparison of the descriptive statistics for the two groups for MA139 revealed that the mean, median and mode were all higher for the multimedia group, and the range of scores was smaller for the multimedia group (See Table 1). For the final scores of Groups 1, the range was 99.50%, the median was 71.90%, and the mode was F. For the final scores of Groups 2, the range was 89.20%, the median was 75.30%, and the mode was B (89.5%-100% = A, 79.5%-89.4% = B, 69.5-79.4% = C, 59.5%-69.4% = D, 0-59.4% = F). Although there was not a big difference between Group 1 and Group 2 in terms of median, the outliers in Group 1 greatly lowered the group's mode because 29 students got F in Group 1 versus 13 students in Group 2. Had the outliers been excluded, C would be the mode for Group 1 and B for Group 2. An independent samples t-test was then conducted using SPSS (Statistical Package for the Social Sciences) to determine if there was a significant difference in final scores between the two groups of students who participated in this study. The mean score for Group 1 was 56.36% (SD = 32.00 percentage points) whereas Group 2 was 70.68% (SD = 19.03 percentage points). The results of the t-test revealed a statistically significant difference between the two groups ($t = 3.52$, $p = .001$), indicating that Group 2, where multimedia was used, had performed considerably better than Group 1, where no multimedia was used. There was a mean difference of 14.32 percentage points between the two groups.

Table 1. Medians, Modes and Ranges for the Two Groups

	Median	Mode	Range	N
Group 1	71.90%	F	0.5%-100%	13
Group 2	75.3%	B	10.8%-100%	29

In order to find out students' perception of multimedia, we administered an online survey toward the end of each semester for the Group 2 students (enrolled in the MA139 with a multimedia component). As Table 2 below, Group 2 students in general had a positive experience with the technology used in the sections they were in. For example, the students were 100% positive about the multimedia instructional materials when asked about their experience with multimedia in the course (Table 2). Similarly, most of the students have positive experience with animation, interactive exercise, text-audio-video, and YouTube video.

Table 2. Multimedia and Student Experience

Media	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Total
Multimedia in general	6	9				15
Animation	2	11	8	1		22
Interactive exercise	7	4	6			17
Text-audio-video	4	7	4	1		16
YouTube video	8	4	1		1	14

MA123 Mathematical Modeling and Reasoning

Attempting to measure the impact of the use of technologies to create an engaging and cross-discipline active learning experience, one set of data collected for this study was from MA123 Mathematical Modeling and Reasoning. While designing an innovative curriculum, the instructor created projects that are relevant to students' life and experiences, and assisted students in acquiring knowledge and skills that will help them to become successful members of society and prepare them for a wide range of professions.

One of the projects in MA123 was a personal finance project. The project introduced low-risk and high-risk loan plans with low and high interest rates respectively, where all the other loan parameters were matched for both plans. The students were asked to consider scenarios of paying off a credit card loan. The first objective was to examine how the interest rates affect the total amount of interest paid for the term of the loan. The second objective was to determine real-life strategies that would help a loan holder to reduce the total amount of interest paid.

The MS Excel dashboard was created for this project in advance by the instructor. A dashboard is a visual representation of key metrics that allow one to quickly view and analyze the data in one place. Dashboards not

only provide consolidated data views, but a self-service business intelligence opportunity, where users are able to filter the data to display just what's important to them. This dashboard is easy to use, and has a dynamic display of graphs and tables. MS Excel tools and functions provide the ability to create dashboards with focus and emphasize on specific learning objectives. For example, Figure 1 illustrates a sample dashboard for this project with four different views. First, the upper-left table in Figure 1 is the data entry location where students can enter the given inputs under the column named "Enter Values Below." To be specific, the students are asked to enter the loan amount, number of regular payments per year, low-risk interest rate, high-risk interest rate, and loan term. As soon as these required values are entered, the amounts for regular payment for low-risk and high-risk loan are immediately computed, shown, and highlighted in the last two rows of the table. Second, based on the inputs, two graphs of the cumulative interest paid in the loan term are instantly displayed in the lower-left of Figure 1, where the high-risk case is in red and the low-risk case is in blue. Finally, upon entering the data, a spreadsheet on the right side of Figure 1 spells out the detailed information, where the table on top is for a low-risk loan and the table at the bottom is for a high-risk loan, and each table includes the columns indexed by number of months, monthly payment, monthly interest payment, accumulated interest amount, the sum of principle and the interest up-to-date, the remainder of the principle, and extra payment.

Figure 1. Finance Project Dashboard: Paying off a Credit Card Loan

One of the advantages of using dashboard for this project is that it creates interactive data visualization, and presents data in a meaningful way. Once data are entered, the dashboard provides computational outputs, displays these results in graphs instantly, and exhibits in spreadsheets simultaneously. These comprehensive reports can then be used by students to analyze and draw conclusions, even make recommendations.

Another advantage of using dashboard is that it is interactive. The students can manipulate the data, change the inputs, and observe the outputs. For example, the spreadsheet located on the right side of Figure 1 allows students to observe the impact of extra payments on accumulated interest amount. Students can make changes to

the amounts of regular or extra payments, and observe their immediate effects on other factors, such as accumulated interst paid or the amounts of principle. Since the project focuses on the accumulated interest amount, the upper portion of the spreadsheet on the right of Figure 1 reports the data for the low-risk loan, whereas the lower portion describes the data for the high-risk loan.

The purpose of the last column of both spreadsheets of Figure 1 is designed to interact with the user for extra payments. For example, suppose a $50 regulator extra monthly payment is entered and applied to the low-risk loan; as a result, the loan would be paid off in 48 months (i.e., four years), which is one year earlier than the five-year loan term, and the amount of accumulated interest paid would be reduced to $3,682.16 from the original amount of $4,753.14 that should be paid in a scheduled 5-year term loan. Similarly, suppose a $50 regulator extra monthly payment is entered and applied to the high-risk loan, then the loan would be paid off in 47 months (i.e., three years and 11 month), which is one year and one month earlier than the five-year loan term, and the cumulative interest paid would be reduced to $8,338.42 from the original amount of $11,250.24 that should be paid in a scheduled 5-year term loan.

The use of such dashboards is very convenient for instructors and students. The project conditions can be easily modified, and students can simply change the inputs, experience various scenarios, then analyze and draw conclusions. In particular, it is not necessary for students to memorize formulas; once the students know how to use this tool, they may use this tool in their daily lives such as when purchasing cars or houses, investing in financial market, taking personal loans, or paying off debts. This project is closely related to students' life and experiences, and helps prepare them for their future daily lives.

Modern technologies allow model life-related simulations, which are beneficial in the learning process. They are helping more effectively to connect education to real-life experience. The multimedia survey was also taken in MA123 classes in the middle of the Spring 2024 semester. A total of 17 student responses were collected and summarized in Table 3.

Table 3. Multimedia and Students' Preferences

Media	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Total
e-Text/Class Notes	5	7	4	0	1	17
Audio/Video	9	5	3	0	0	17
Animations	2	6	9	0	0	17
Interactive exercise	4	7	4	2	0	17
YouTube Videos	8	4	3	2	0	17
Class Recordings	3	4	8	2	0	17
Multimedia is Useful	4	9	4	0	0	17

Table 3 indicates that audio/video (provided in the the course) is the most perferred media where14 out of 17 students were in favor of using video as the supporting learning source while working on the assignments; it was followed by the usage of YouTube videos, where 12 out of 17 students were in favor of YouTube videos (searched by students). On the other hand, it seemed that the post Zoom lecture recordings was used not as much as other media catagories, and it was the last resort for the students if they exhausted all other resources and still couldn't figure out solutions for the problem. Finaly, 13 out of 17 students favor using multimedia as supporting material for studying homework assignments. The survey showed that multimedia played an important role in the students' learning process.

In addition, feedback from students in MA123 Spring 2024 and MA123 Summer 2024 classes showed: "*...I did appreciate having the assignments online making it easier for feedback when and wherever I did my homework...Projects 3 & 4 made the most sense going over the materials that we covered"*; "*Really understandable and appreciate your way of teaching"*; "*The course was taught really well, and the instructor Natalya Kiselyova did an excellent job at teaching and making the class interesting"* (MA123, Spring 2024) *"This course has been highly organized and easy to follow along. The instructor answers emails and grades assignments in a timely manner. She was incredibly helpful by meeting with me via Zoom to discuss an online project in detail. This has been one of my best experiences in an online college course!"*; "*This is my third time attempting this class and this was by far my favorite instructor. I really liked the way the class was organized. The instructor communicated regularly and laid out clear expectations for the class."* (MA123, Summer 2024) Based on these comments, it is obvious that students appreciated the online homework system, especially the immediate feedback from the instructor, and they liked the options of trying similar problems as needed. The students felt they learned from projects 3 and 4, where they created linear and exponential regression models and determined the best fit model for provided project data in project 3, and managed personal finance—paying of a credit card loan in project 4. Both projects connected students to real-life scenarios, and helped them understand the class materials. It appears that the activities and projects made class more interesting, and the implementation of technologies in the curriculum helped students learn skills that could be useful outside of the classroom. Finally, the last two comments from Summer 2024 indicate the importance of communication in online class. For online classes Zoom office hours were provided at scheduled times and by appointments. Zoom office hours provided students with much more flexibility and greater opportunities to access help than were available before the Zoom era. Zoom made it possible to communicate with an individual or a group of students at the same time. For example, as soon as one student scheduled an appointment to discuss a project via Zoom, the details of the Zoom session including the potential discussion topics would be sent to the entire class by an email to invite all the students to participate in this Zoom discussion. Usually, as a result, an additional two or three students would join this Zoom session, and hence more than one student would benefit from this project discussion. This shows that applications like Zoom bridge the communication gap between students and instructors in online classes, and increase the quality of communication in an online environment closer to that in a face-to-face setting.

In summary, students comment clearly indicate that technologies provide a more engaging learning environment, improve the collaborations and communication among students and instructors, and enhance time-on-task classroom management. Technologies assist the instructors in delivering lectures more smoothly and more effectively. In addition, technologies connect students and instructors in online study groups, and help mitigate feelings of isolation. There is no doubt that technologies help mitigate the challenges of online learning and improve the quality of virtual teaching and learning.

Conclusion

Technology, multimedia in this case, seems to have made a big difference on student performance in online instructional environments, as the quantitative data showed. Various factors may have contributed to the positive difference multimedia made; for example, its visuality and animation can make learning engaging and active, its 24/7 accessibility affords students autonomy and control over pacing and sequencing of the learning content, its motion capability and revealing process of deduction and reduction enable students' knowledge retention and its application. Multimedia, therefore, can extend and augment students' learning experience as it capitalizes on the characteristics of each individual. There was abundant qualitative evidence from student testimonials why technology in general, and multimedia in particular, made a difference.

While both qualitative and quantitative data demonstrate that in the same online instructional environment, using multimedia will effectively improve student performance, further studies may reveal whether the demographics of student also contribute to student performance, for example, their gender, age, marital status, and employment status. As well, it will be interesting to see whether the students' improved technology skills are another contributing factor to improved student performance. Our hope is that with the passage of time, as students became more proficient in the use of technology, the demand for all online offerings will keep growing. Future efforts may be made to identify and exclude those outliers such that the data will more accurately reveal the impact of multimedia on the performance of students taking online math course. As well, efforts may also be made to improve the quality of multimedia presentation such that it will do more (i.e., development of more multimedia instructional materials for teaching and learning, and more in-depth content analysis, illustration, and/or demonstration), and to replicate the dynamics in a face-to-face learning environment.

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