A MIXED METHODS STUDY OF ENGINEERING UNDERGRADUATES' ADAPTIVE LEARNING EXPERIENCES

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ABSTRACT

Open-access online courses, called massive open online courses (MOOCs), have received much attention from higher education institutions and course designers for their potential to reshape learning opportunities. Among the challenges in learning from MOOCs or in an online setting is that students may have insufficient prerequisite knowledge about the topic being presented. If so, students may have a limited understanding of the material and they cannot ask questions in person to clarify their understanding. To address this problem, researchers have been developing adaptive learning technologies. Adaptive learning is a form of learning in which a computer changes the lecture content to best fit a given student based on the student's interactions with the interface. However, current literature suggests that behavioral patterns such as boredom or frustration in adaptive online learning tasks should be explored in order to improve students' learning experiences. This study investigated engineering undergraduate students' perceptions of an adaptive learning environment using MOOCs materials. In this exploratory mixed-methods study, we collected and analyzed survey and interview data and post-test scores for 18 students in our experiment. The results of the evaluation suggest a negative correlation in the relationship between students' learning gains and their perceptions of their enjoyment of the videos.

KEYWORDS

Adaptive Learning, MOOCs, Personalized E-Learning

1. INTRODUCTION

Over the past decade, massive open online courses (MOOCs) have received a great deal of attention in the education field (Gaebel, 2013). MOOCs provide high-quality learning resources for millions of students to access at their convenience, at little or no cost. However, MOOCs come with many challenges. One challenge is that although many students enroll in MOOCs, the retention rates for these courses are very low and only a very small proportion of students complete the courses (Khalil & Ebner, 2014). According to Belanger and Thornton (2013), another challenge is that students who participate in MOOCs may have insufficient prior knowledge about the course topic. This may lead to their becoming frustrated while watching a MOOC, and being unable to process the material they are learning. As a result, they may be unable to go on to the next steps. Furthermore, while using MOOC content, students may have no one to turn to for help (Belanger & Thornton, 2013). Therefore, the second main problem with MOOCs is that personalized support is unavailable to students and there is a lack of interaction between instructors and students (Zhang, Zhu, Wang, & Chen, 2018).

According to Brame (2016), there are three elements that must be considered in educational video design and implementation in order to keep students engaged and for the video to serve as a productive part of a learning experience. They are: (1) cognitive load (channels relate to where the processing of the incoming information takes place); (2) non-cognitive elements that impact engagement (e.g., shortness of content-delivery segments and a conversational style of delivery); and (3) features that promote active learning (e.g., interactive activities, homework).

Also, Guo, Kim, and Rubin (2014) state that in order to optimize the cognitive load and keep students engaged during an e-learning experience, it is recommended that videos be kept short, preferably under 6 minutes. Furthermore, appropriately using both auditory and visual channels in videos has been shown to maximize students' retention of the material and increase student engagement (Guo et al., 2014). Guo et al. (2014) also reported that student engagement was dependent on the narrator's speaking rate, such that student engagement increased as the speaking rate increased.

One way to help students and to enhance their online learning experiences would be to develop intelligent tutoring systems that provide additional explanations of materials to learners (Aleven & Koedinger, 2002). Building on decades of research in intelligent tutoring systems, psychometrics, cognitive learning theory, and data science, researchers have developed adaptive learning technologies (Rosen et al., 2018). The defining feature of adaptive learning is that a computer algorithm analyzes the student's interactions with the interface and changes the lecture content to best fit that student. However, Rosen et al. (2018) suggested that behavioral patterns in learners in performing adaptive tasks should be explored in order to identify ways to improve adaptive tasks (Rosen et al., 2018). Our research study explores the effects of adaptive interactive tasks from students' perspectives and potential factors that might improve adaptive learning environments.

It is clear that MOOCs providers want students to learn as much as possible. But currently, the dropout rate is really high due to learners' frustration with online learning. However, minimal data exists in regard to what factors may contribute to online learners' frustration in an adaptive learning environment (e.g., too many adaptive quizzes, monotony of the lecturer's voice, etc.). As a result, these factors may lead learners to dropout or quit. The purpose of this experimental pilot study is to explore how students' adaptive learning experiences influence their levels of frustration and enjoyment using online learning modules.

2. DESCRIPTION OF EXPERIMENT

The primary purpose of the research study was to explore how students' perceptions of adaptive learning environments are related to frustration with and enjoyment of the modules. To this end, we developed and executed an exploratory mixed methods research design (Creswell, 2002), which involved surveying and interviewing participants to investigate their adaptive learning experiences. The experiment was conducted to address the following hypothesis: As students are exposed to an adaptive learning environment, they may experience frustration, but also an increased sense of enjoyment.

We analyzed the survey and interview data to elicit the most emergent themes. Ultimately, we hope to: (1) understand whether students become frustrated in engaging in adaptive learning environments and, if they do, why and (2) determine whether students' enjoyment increases due to engaging in an adaptive activity. In the following paragraphs, we detail the procedures used to conduct the research study.

2.1 Participants

In order to have a population with the same amount of knowledge, it was essential to recruit students with little exposure to the lecture topic featured in the online learning material. This allowed us to measure learning gains across students with the same knowledge level of the topic. Thus, we initially attempted to recruit University of Michigan (UM) engineering undergraduate students who had not taken any industrial and operations engineering (IOE) courses. If they had not taken any IOE courses, then it was more likely possible to measure their learning gains related to the topic material. In a previous study, Pomales-Garcia and Liu (2006) recruited 18 participants to effectively analyze learners' perceptions and the impact of web modules on their learning experiences. For this pilot study, after receiving approval from the UM Institutional Review Board, we requested that department program coordinators distribute the recruitment email through their undergraduate email listservs. We recruited 18 UM engineering undergraduate students for our sample population.

The average age of the sample was 20.38 years, and the average GPA was 3.48 on a 4.00 scale. Among the participants, 10 students were male and 8 students were female. Participants self-identified their racial backgrounds as: Asian (9), White/Non-Hispanic (5), Hispanic or Latinx (2), American Indian or Alaska Native (1), and Black or African American (1). The participants' demographics by academic major were: Mechanical Engineering (9), Industrial Engineering (5), Chemical Engineering (1), Biomedical Engineering (1), Civil Engineering (1) and Not yet declared (1).

2.2 Instruments and Data Collection Procedures

A survey and interview protocol were developed to collect information about participants' experiences in performing adaptive learning tasks in an adaptive learning environment. Demographic information (i.e., academic major, race, gender, etc.) about participants was also collected.

2.2.1 Learning Modules Materials

To examine the effects of the adaptive learning environment, the experiment consisted of participants watching a 20 to 30 minute lecture that included adaptive tasks (for each concept that was covered), intermittent assessment (approximately 3 to 10 minutes) of the participants' content knowledge via survey, and then interviewing the participants about their experiences. Specifically, we created an adaptive learning task experience for participants using online learning videos from YouTube and electronic survey software. The chosen topic for the video lecture was basic Economic Order Quantity (EOQ), which focuses on optimizing order quantity to minimize total costs. This concept requires that a student be knowledgeable about economic concepts, calculus, and inventory management. We first created the video module by splicing together content from existing YouTube videos that had the most views about EOQ topics. Then, we created a survey of content knowledge questions using Qualtrics software that asked participants questions after each topic was taught.

2.2.2 Survey Protocol Development

The study's survey consisted of nine questions. Six questions requested demographic information (e.g., race/ethnicity, sex/gender, academic status, age, major, and citizenship status). In addition, three survey items were modified and adapted from Pomales-Garcia and Liu (2006). These questions asked participants to rate their own perceptions of knowledge (i.e., understanding of the material presented in the video) gained using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). This was done to collect information about their perceived adaptive learning experiences as quantifiable data. These questions were:

a) Before watching the video modules, how much did you know about the topic discussed in the module using a scale of 1-5, where 1 = completely new material and 5 = expert?
b) After watching the video modules, how much did you know about the topic discussed in the module using a scale of 1-5, where 1 = completely new material and 5 = expert?
c) If the rating for the level of difficulty of a children's story for a four-year-old represents a rating of 1, what is the level of difficulty of the content that this module presented?

2.2.3 Interview Protocol Development

We created an interview protocol composed of 17 questions. The interview protocol was developed in collaboration with mixed methods study experts in Dr. John W. Creswell's mixed-method workshop in 2018. The interview questions required the participants to offer more details about their adaptive learning experiences in the pilot study. The first question asked participants about their overall adaptive learning experience. The interview questions focused on three sets of themes: frustration, attention level, and enjoyment of the material. Rosen et al. (2018) suggest that behavioral patterns in adaptive tasks should be explored. Thus, we created interview questions that examined three topics: (1) enjoyment: the enjoyment students experience in an adaptive online learning environment; (2) frustration: the frustration students experience in an adaptive online learning environment; and (3) online video usage: students' use of online videos as an educational supplement. For each topic element, there were corresponding interview questions. For enjoyment, there were six questions (e.g., "What did you like about your experience in completing the module?"). There were six items that measured frustration (e.g., "Describe a time in this process in which you felt frustrated"). For the topic of online video usage, there were two questions (e.g., "Do you use online videos or MOOCs as a supplement in your studying?"). The two final questions inquired if participants wanted to provide any additional thoughts about the overall experience, and, finally, if there were any final thoughts they would like to add in general.

2.2.4 Administering the Survey and Interviews

Survey response data was collected using an online Qualtrics survey. To maintain participants' privacy, the names of the participants were changed to pseudonyms and any identifiable information has been removed from the reported data. The interview voice recordings were transcribed verbatim by the first author. Voice recordings were deleted immediately after the transcription. Prior to conducting this research, this study was approved by the UM Institutional Review Board.

2.2.5 Experimental Procedure

The experimental procedure consisted of several steps. First, the researcher discussed the outline of the procedure with the participant, and then the participant signed an informed consent form. Next, the participant watched the adaptive video lecture lesson, and then took a post-test. The post-test consisted of questions about EOQ topics to assess students' knowledge of what they had learned in the video. Next, the participant completed a survey that collected demographic information and examined their learning experience and, finally, participated in an interview with me in which data was collected using the Samsung Galaxy s6 voice recording program. These procedural steps are discussed in detail in the following sections.

2.2.6 Lecture Procedure

After consenting, the participants went through a lecture procedure that involved watching a video lecture and taking content quizzes at specific places in the video. Specifically, the participants performed the following steps:

(1) Video: Participants watched a video about an EOQ topic.
(2) Content Quiz: After each topic was explained, the system displayed a short multiple-choice quiz about the topic. There were three questions asked per adaptive task. The adaptive tasks were administered two times. There was one content quiz administered at the end of the lecture procedure.
(3) Remediation Videos: After the participants completed the content quiz, they were administered one of two types of remediation videos (i.e., short and long). Remediation videos are additional videos that provide a more detailed explanation of the video that they watched. Shorter remediation videos (3 minutes) were shown to the first nine participants who participated in the experiment, and longer remediation videos (8 minutes) were shown to the remaining nine participants. This was done to initially examine how the length of the remediation video affects students. However, we did not find any significant effect on students.
(4) Post-Test: Following the lecture procedure, all participants took a post-test about what they had learned. The post-test consisted of eight questions about EOQ topics to assess students' knowledge of what they had learned during the whole learning process. An example of a post-test question is: "What would happen to economic orders quantity if other items remained the same in the EOQ model, with double annual demand and double the unit cost of purchased materials?"

2.2.7 Administering the Survey and Interview

After participants completed the post-test, the researcher administered a survey to collect information about participants' demographic characteristics and their experiences. After the participants completed the survey, we conducted interviews with them. The interviews were conducted in an enclosed room. The interviewer asked questions and the interviewee answered in a conversational style. This allowed us to see in detail what the students were experiencing during the learning process.

3. DATA ANALYSIS

After the data collection procedure, we used quantitative (e.g., descriptive statistics) and qualitative (e.g., thematic analysis) methods to analyze the survey and interview data, respectively. Three themes (i.e., Enjoyment, Frustration, Use of Online Learning) were explored qualitatively. First, we performed descriptive statistics analysis and organized students' responses according to the corresponding theme. Then, we transcribed the 18 interviews. Finally, we thematically analyzed the interview data to identify major emergent themes (Creswell, 2002). Details about steps performed in analyzing the data quantitatively and qualitatively are explained in the following sections.

3.1 Quantitative Phase

We wanted to explore the differences in frustration between students who did extremely well on the post-test (scored 100%) and students who did not. Therefore, we divided students into two groups: those with perfect scores and those with non-perfect scores. Then we looked at each score group's transcribed data. From the transcribed data, we divided the data into groups of students who expressed that they were frustrated and those who did not express that they were frustrated about the adaptive learning environment. Next, we tallied how many students were in each category. The findings are displayed in Section 4. Within the group of students who expressed frustration, we qualitatively explored why they were frustrated, which will be explained in the next section.

To investigate whether and why students use online videos as educational supplements, we coded the transcribed data into themes. We tallied how many students used online videos to supplement their college study and learning experiences. Then we organized these results.

To assess the correlation between students' post-test scores and their perceptions about the enjoyment gained from the adaptive learning activity, we assessed Pass/Fail scores. First, we collected test score data. Then, a Pass was assigned to scores greater than 70 out of 100 points. Under the enjoyment data, we filtered data corresponding to students who passed and those who failed. Next, we tallied how many students were in each group.

3.2 Qualitative Phase

Interview transcripts (n = 18) were thematically coded and used in conjunction with the descriptive statistics information to explore and understand how learners' perceptions of learning environments were affected by the adaptive tasks and the explanation videos. Specifically, thematic analysis (Boyatzis, 1998) was performed using the following method. First, using the interview data, we assessed and categorized participants' most frequent and common responses that arose about frustration, enjoyment, and the use of online educational videos. Answers that commonly arose were grouped into the same category theme. For example, six students expressed that they were frustrated with the professor's tone and energy. Their specific responses were grouped into one qualitative category (i.e., frustration) to assist with further interpreting the quantitative data. Specifically, the interview data allowed us to examine similarities or differences in the interviews of participants and their descriptive statistical data in frustration and enjoyment and the use of videos. The data analysis findings and a discussion of the implications of this research are presented in the next section.

4. RESULTS AND DISCUSSION

From the data, three main themes emerged about engineering undergraduates' adaptive learning experiences in regard to enjoyment, frustration, and online video usage. Those themes are: (1) Adaptive Learning Environments are Enjoyable, (2) Frustration Linked to Teacher Energy and Lack of Student Knowledge, and (3) High Rates of Online Video Usage as Educational Supplements.

4.1 Adaptive Learning is Enjoyable

Findings seem to suggest that students found the adaptive learning experience enjoyable. Among all students who expressed that the overall adaptive learning process was helpful and enjoyable (n = 15), approximately half (n = 8) earned a passing quiz score (i.e., more than 70 out of 100 points).

It is clear that MOOCs providers want students to learn as much as possible. But currently, the dropout rate is really high due to frustration. However, there is minimal data that exists in regard to what factors may contribute to online learners' frustration (e.g., too many adaptive quizzes, monotony of lecturer's voice, etc.). As a result, these factors may lead learners to dropout or quit. The purpose of this experimental pilot study is to explore how students' adaptive learning experiences influence their levels of frustration and enjoyment in using online learning modules.

Some of the reasons about enjoyment given by students who did not earn a passing score were:

> *"It (the learning experience) was interesting. It (if I already knew the material) would save me a lot of time because if I already learned most of it or just the little things here, then I can move on to different videos."*

> *"It (the learning experience) was good. I liked (that) the quiz asked about content that's included in (the process). That's great because I have that question in mind so the next video, I could expect the video to talk about it."*

> *"I thought it (the learning experience) was great. I feel like this can be used to bridge the gap instead of watching the whole lecture."*

From the data, it seems that students perform more poorly in retaining online content knowledge if they do not enjoy the online video. Specifically, findings seem to suggest that there is a negative relationship between students' final post-test scores and their perceptions of enjoying the video. This might occur because the videos automatically display information for students and reduce students' motivation to search for examples. This relationship suggests that the adaptive learning environment may play an important role in facilitating help, but it also reduces students' germane load (i.e., a cognitive activity that deals with interpreting, exemplifying, classifying, inferring, differentiating, and organizing).

4.2 Frustration Linked to Teacher Energy and Lack of Student Knowledge

Results seem to indicate that students' frustration with the adaptive learning tasks may be linked to the monotony of the video instructor or the students' own lack of content knowledge. In regard to the theme of frustration, among the 12 students (n = 12) who did not achieve a perfect score on the final test, 50% of those students found the adaptive learning session frustrating.

When asked in the interview, 50% of students said that they felt frustrated. We found two different reasons why students were frustrated: (1) they did not like the energy (i.e., monotone and low enthusiasm) of the teacher in the video; and (2) they lacked knowledge about the adaptive tasks they were tested on. Some of the quotes about frustration given by students were:

> *"I was frustrated when he (the video instructor) took a while to explain things."*

> *"This video (...) was like boring, it was like slow sort of, but not really due to the content."*

> *"When the quizzes were talking about something else (I had not learned yet), it was kind of confusing at first."*

Similarly, among the six students who performed perfectly on the final test, 50% (n = 3) found the adaptive learning session frustrating because it tested them on the knowledge that they did not yet possess. Both groups (frustrated and not frustrated) stated that, after they watched the remediation videos that explained the missing concept thoroughly, they felt more confident about the process.

From the findings, it seems that students got frustrated engaging in the adaptive learning activity when they did not know the answers to questions they had not learned about. In particular, the adaptive task questions were designed in such a way that if students had strong backgrounds in mathematics and/or economics, they would be able to solve the mini-adaptive tasks. However, the adaptive learning process may have created students' frustration because the initial instructions were not clear. The tasks tested them on the knowledge that they did not yet possess.

According to one study, researchers found that engaged concentration and frustration are correlated with positive learning outcomes (Pardos, Baker, San Pedro, Gowda, & Gowda, 2013). Therefore, it is worthwhile to examine ways to reduce students' enjoyment of a video while increasing the frustration necessary to evoke a student's positive learning gains. Furthermore, it is valuable to explore what factors in adaptive learning environments create frustrations that add value to students' learning gains, as well as what factors do not add value. According to Guo et al. (2014), using a conversational, enthusiastic teaching style enhances students' engagement. The current study results seem to support their conclusion in that some students found the adaptive learning session frustrating because the energy of the teacher was low. Thus, to reduce students' frustration, videos with a conversational and enthusiastic style should be selected for use in adaptive learning environments.

4.3 High Rates of Online Video Usage as Educational Supplements

The data seems to suggest that students use online videos to help supplement their understanding. From the interview data, in regard to online education, 94.4% of the participants (n = 17) indicated that they use MOOCs or YouTube Education videos outside of school courses to help them with concepts. Some students explained how they used online educational materials:

> *"I watch Khan and YouTube videos. I take like bits and pieces (of) knowledge that I need help (with) for school."*

> *"If I am looking for a specific topic that I don't understand, I just search on YouTube instead of having to browse through an entire (set of) notes."*

> *"If a professor doesn't really explain it (a specific topic) all the way, I prefer using online videos because I can pause (the videos and watch) it over (again)."*

Students seem to regularly use online videos as supplemental learning tools. In Jaffar (2012) descriptive and experimental study on college students (n = 91), he illustrates that 98% of respondents were using online learning videos as a source of information. Even though our study is based on a smaller sample size (n = 18), our result is consistent with Jaffar's result by indicating that more than 90% of engineering undergraduate students are using MOOCs or YouTube Education videos outside of school courses.

Results from this study may reinforce the claim that online video education has become essential for new millennial learners in their undergraduate learning. Therefore, teachers and online course designers should also increase their efforts to continuously improve online teaching quality in order to help students.

4.4 Limitations

This study has some limitations. First, the sample size was very small. However, as a pilot study, this study assists in determining an experimental research design for future research on frustration, enjoyment, and the use of online educational videos. Second, this study is limited in its analysis of the behavior of learners who participated in an adaptive learning activity featuring MOOC material from a single lecture. Learners viewing or posting comments were not considered. Future research should examine how MOOCs' forums and posted comments may also play roles in affecting students' adaptive learning experiences. Third, this study focused on using thematic analysis of the qualitative data. Future research studies could employ more advanced statistical analyses to analyze the frustration and engagement of learners in adaptive learning environments.

5. CONCLUSIONS AND FUTURE WORK

Prior research suggested that behavioral patterns in adaptive tasks should be explored in order to improve students' learning experiences (Rosen et al., 2018). Using collected survey data, interview data, and post-test scores from the 18 students in our experiment, this study investigated engineering undergraduate students' perceptions of an adaptive learning environment. After the data collection, an analysis of the descriptive statistics and interview data were used to identify emergent themes. In this experiment, the results suggest that there may be a negative correlation between students' learning gains and their perceptions of enjoying an adaptive task.

There were several insights gained from this pilot study that may help to inform the design of future research studies of adaptive learning experiences. First, we learned that for future research studies, we will administer a pre-test to all students before they engage in the adaptive lecture lesson. This will allow us to compare learning gains across students who perform various adaptive tasks. Also, future research designs should use a machine learning model to better predict the learners' path. In addition, detailed qualitative data collected through open-ended interview questions should be used to better understand the quantitative data and the survey results.

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