Designing Interactive Videos in Online Multivariable Calculus Course to Support Student’s Critical Thinking

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Abstract. Emphasizing critical thinking skills in the curriculum of higher education institutions is needed to produce graduates with higher order thinking skills. Given the importance of information technology for critical thinking in learning, it is necessary to understand the key factors related to learning designs that utilize information technology in their learning environment and consider the pedagogical and information technology alignment. This study aims to describe the process of analysing, designing, and developing interactive learning videos as part of the redesign of the multivariable calculus course to support students’ critical thinking skills. This paper will describe the lessons learned from and the next steps in this research and development process.

1. Introduction

One of the main goals of higher education with the support of information technology is to make students more active in the learning process [1]. The expected outcome of this effort is to cultivate essential skills such as critical thinking. Since critical thinking skills are a high priority and demanded by the job market, educators agree that it should be one of the main concerns for higher education institutions to produce graduates with high-level thinking skills, and these skills should be emphasized in the curriculum [2]. Given the importance of information technology for critical thinking in learning, it is necessary to understand the key factors related to learning designs that utilize information technology in their learning environment and consider pedagogical alignment and information technology.

In Indonesia, national education policy requires that students be able to reason, criticize, know how to solve problems, and apply these skills in real life situations. In addition, in the Partnership for 21st Century Learning, 21st century skills have been used by educators and placed in learning centers [3]. Likewise, educators believe that schools must provide students with broad 21st century skills to thrive in a world that is rapidly developing, saturated with technology [4], and critical thinking is one of those skills. Unfortunately, despite a number of attempts in Indonesia to cultivate critical thinking, the lack of critical thinking skills is still a problem that has not been considered important. One of the contributing factors is the mismatch of the teaching methods used [5]. That is, students are still taught to listen, rather than ask questions [6]. Other factors that contribute to these problems include the culture and education system in schools [7-8].
Lack of critical thinking skills is an existing phenomenon, not only in Indonesia, but in many parts of the world as well. As evidence, the Business Roundtable, a network of corporate chief executives, found in a 2009 survey of 600 employers that it is difficult to find qualified employees who have critical thinking [9]. An exploratory study conducted by Firdaus & Mukhtar [10] shows that 165 students of the Mathematics Education Study Program at Medan State University are only at the average critical thinking level. To overcome the lack of critical thinking skills among students of the Mathematics Education Study Program as teacher candidates, this study proposes an interactive video in online discussions using the online learning system platform, SiPDa.

There are several ways in which videos can make a real difference to teaching and learning in higher education. Oberne [11] states that video in discussion is one way to promote student interactivity in online learning. Literature search by Taslibeyaz et al. [12] in the context of medical education from 2000 to 2014, showed that by watching videos students gain clinical skills, change attitudes, encourage cognitive learning, and increase knowledge. Yousef et al. [13] found some evidence that the use of video-based learning saw improvements in teaching methods and learning outcomes. However, determining whether interactive video can be used as an effective tool in supporting critical thinking skills in a higher education setting was identified as a research gap that requires greater exploration. This is because only few researches are available that proves the development of critical thinking in the context of video learning [14].

Because students are currently categorized as digital natives and the use of technology is a trend in teaching and learning [15], information technology can be integrated into online learning models. Therefore, this study seeks to integrate interactive video with information technology through the SiPDa platform which facilitates online learning at Medan State University. The main focus of this study was to develop and produce instructional interactive videos, which aimed to replace traditional in-class lecture and free up class time for more active learning opportunities.

2. Methodology
This study was a research and development study. The product development process follows the ADDIE model which consists of 5 stages: analysis, design, development, implementation, and evaluation. Each stage involves two education experts (lecturers with doctor degree in the Mathematics Education Study Program at Medan State University) and two practitioners (lecturers in the multivariable calculus course) as speakers in focus group discussions. Researchers, subject matter expert (SME), educational technologist (ET), eLearning designer (ED), animator, graphic designer (GD), and video editor (VE) were involved in developing the interactive videos. To help determine an interactive video design plan, the multivariable calculus instructional videos available on the internet were reviewed and analyzed. A total of 169 students enrolled in the multivariable calculus course were involved in analysis and implementation stage. The target audience was obtained from a simple random cluster sample using the lottery method. The standard Watson-Glaser Critical Thinking Appraisal test was used and delivered online. The reliability was calculated as 0.76 reliable using Cronbach’s alpha.

3. Results and discussion
The course structure of the Multivariable Calculus in face-to-face classes includes two sessions: a 100-minute face-to-face lecture and a 50-minute discussion. The online course structure in this study, students complete watching instructional videos that are complemented by exercises before online discussion sessions. Before starting the second session, students solve a collection of problems in the assessment delivery system. During the second session, which is a discussion format, students work on a collection of written problems in groups organized by the lecturer. Each week the course ends with an online quiz and submission of problem sets.
3.1. Analysis

Student’s critical thinking skills was analyzed and some multivariable calculus instructional videos available on the internet were reviewed and analyzed to help determine an interactive video design plan.

3.1.1. Student’s Preliminary Critical Thinking Skills. Among 169 students enrolled in the multivariable calculus course, 164 students participated in the test and the results are described in Table 1.

| Subscale                | Minimum | Maximum | Mean  | Standard Deviation |
|-------------------------|---------|---------|-------|--------------------|
| Arguments               | 29      | 100     | 55.62 | 12.94              |
| Assumptions             | 16      | 100     | 46.31 | 13.61              |
| Deductions              | 27      | 100     | 58.76 | 12.56              |
| Inferences              | 15      | 100     | 24.37 | 11.34              |
| Interpreting information| 16      | 100     | 52.13 | 12.47              |

The results indicated that the grades of student’s critical thinking skills varied between 30 and 90 in possible maximum grade 100. The mean score of 51.2 with a standard deviation of 7.54 fell within the 30th – 60th percentiles could be interpreted as “average.” The descriptive data regarding subscales are presented in Table 2.

3.1.2. Instructional Videos Available on The Internet. Some of the video formats available on the internet fall into one of three categories; (1) recorded in actual classrooms; (2) recorded without the presence of students; and (3) recorded via screen recording in which problem solving is done using real or digital whiteboards and paper.

Recording instructional video in actual classrooms, with or without the presence of students, is probably the fastest way to record and deliver instructions. However, in such a format, effectiveness is something that has to be concerned. Since the format depends on the number of cameras and their location in the room, it is difficult to clearly see the lecturer work on the blackboard which is often obstructed by his body. Students often just watch instead of feeling present in class. Meanwhile, the concern over the video format that records explanations and problem solving by displaying handwritten notes is the aesthetic value created by messy handwritten visuals. Although the screen recording format seemed to be the best choice, this study wanted to ensure that visual, duration, and repetition clutter were avoided.
3.2. Design
Based on the analysis of students’ critical thinking skills and a review of existing videos, it was decided that the interactive videos produced in this study should have the following characteristics: (1) encourage learning experiences that include demonstrations, practice, and formative assessments; (2) workspace that is cleaner, more organized, and easier to read; (3) a better visual representation of the steps in problem solving; (4) inclusion of real-world questions and examples that refer to the five critical thinking subscales; (5) full screen visuals; and (6) a concise and error-free narrative.

Structuring interactive videos that promote learning experiences which include demonstrations, practice, and formative assessment is intended to enable students to master the concepts of one topic through demonstrations by lecturers and measure concept mastery through hands-on practice before they move to the next topic. In addition, this characteristic is also intended to provide opportunities for students to develop their critical thinking skills while participating in problem solving.

3.3. Development
Adobe Captivate e-Learning software is used to incorporate interactive functions into the video. Captivate’s integrated Math Magic equation editor is used to display mathematics and Autograph is used to display three-dimensional graphs. These software allow better visual adjustment of the screen. Animations were added to enhance the visual representation and reveal problem-solving steps. Video scripts are made to anticipate errors in calculations. Storyboards are built for easy timing and scenarios before recording audio and video. Google Drive and Google productivity apps for collaborative content development and management including Docs, Sheets, and Slides are used to build interactive videos. SiPDa learning management system is used to deliver the resulting videos.

The development process begins with completing a list of topics that are in line with the weekly learning objectives. SME sends the script/storyboard to ET for refinement. ET sends the refined script/storyboard to the animator to begin design and production. The animator sends the resulting animation to GD and VE for audio, video and screenshots recording. After recording, GD and VE sent the results to ED to make the first draft of the interactive video by integrating it into SiPDa.

The lesson learned from this development process is that a production process that is comprehensive, clear, and easily adopted must be established at the beginning of production. To minimize confusion in this complex process, SME and ET should simplify the language in scripts/storyboards so that animator and ED without a strong mathematical background can understand the design intent. The steps for correcting errors must also be established at each stage of the production process. As a next step, the produced interactive video will be implemented to assess its effectiveness. During the implementation process, gaps in online and face-to-face teaching and assessment will be identified.

By replacing classroom lectures and textbook reading, interactive instructional videos make the most of instructional delivery possible online. Research has demonstrated the benefits of video-based learning, including flexibility of time and place, unrestricted student access to learning materials, and self-regulated learning [17]. In addition, students’ attitudes towards video imply that this learning format helps their understanding and skill development [18-19].

By integrating interactive videos into a learning management system, practice can be combined with teaching. Bishop & Verleger [20] shows that interactive online videos outperform traditional videos and lectures in enhancing content understanding, and can lead to improved learning outcomes and learner satisfaction [17].

One way of promoting student interactivity in online courses is through discussion or collaboration sessions [11]. The interactive videos developed in this study can facilitate this collaboration in which students and faculty are allowed to interact with each other. Loes & Pascarella [21] showed that exposure to collaborative learning activities affects the development of critical thinking skills.
4. Conclusions

This study is intended to describe the lessons learned from and the next steps in this research and development process. It is the first step in recording and reporting the redesign of the multivariable calculus course to support students’ critical thinking skills.

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