The Contribution of Hybrid Learning in the Teaching of Advanced Mathematical Skills for the Enhancement of Critical Thinking Skills among Students within Indonesia's Higher Education

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Abstract

This study aimed to investigate, if the application of hybrid learning approach in higher education through the teaching of Advanced Mathematical Thinking abilities enhanced students critical thinking abilities. The design used in this study was a strong experimental research design with pretest and post-test control-groups, using randomized designs. The samples of this study were taken from two classes which were used as the experimental class and the control class. The population studied comprised students of a mathematics education study program at a university within Bandung city who attended lectures for the multivariable calculus course in 3 classes with a total population of 125 students. The instrument in this study consisted of two types of instruments, namely: the test and non-test instruments. The results of the normality assumption test on the Advanced Mathematical Thinking variable based on the Learning Method Factor obtained a significance value greater than 0.05 ($p>0.05$) meaning that it is normally distributed. It was established that hybrid learning treatment class attained Advanced Mathematical Thinking abilities.

Keywords: Advanced mathematics skills, Critical thinking ability, Hybrid learning, Innovative teaching, and Teaching mathematics.

Introduction

Enhancing students thinking skills is of great importance for personality growth and development [1] in society. In higher education, critical thinking skills is highly required, because it is the basis for fluent communication and advanced problem solving [2] and also helps students overcome their egos [3], hence leading to better interaction and cooperation among learners. Students critical thinking skills is fundamental in higher education due to the fact that it develops memory, cognition and metacognition which affect understanding [4]. Preparing university students for the world outside the education arena requires better teaching and learning approaches [5] which can help students better prepare for the complex challenges the world presents [6]. In other words, education must be able to prepare a generation that is able to answer most challenges and life scaring hazards by preparing as persons who are capable in problem-solving, skilled, critical and creative.

Critical thinking skills, being one of the required 21st century skill, Indonesia's Ministry of

Education and Culture tasked teachers to sharpen their critical thinking abilities [7]. However, through document analysis it has been established that most of Indonesian students, including those in higher education, still lag behind other countries regarding critical thinking [8]. It is upon this background that the present paper looks at Hybrid Learning in the Teaching of Advanced Mathematical skills for the enhancement of critical thinking skills among students within Indonesia's higher education. In relation to students critical thinking abilities, in a study conducted by Trends in International Mathematics and Science Study (TIMSS) (2011), as an institution that measures world education, ranked Indonesia 38th out of 63 countries in learning mathematics.

The aspects assessed in mathematics are knowledge of facts, procedures, concepts, application of knowledge, and understanding of concepts learning, which are influenced by students thinking ability. The TIMSS results can be used as information to measure students' conceptual comprehension abilities, which in this case are still considered low on the Indonesian side. One of the reasons is because teaching and learning activities are more dominated by teachers, thus student responses are mostly in form of stories, and they have difficulty solving questions that are different from the way they have been taught by the teachers. This affects learning motivation, coupled with reduced study hours in schools leading to limited time appropriate for one to attain the required subject matter, more so regarding understanding advanced mathematical concepts.

Mathematics is an important element in our lives, so learning mathematics is very necessary. People at work in almost all in fields need mathematics to think by reason, logically when applying numbers, think critically on population issues or beneficials of any given program, think creatively, communicate well, predict and make decisions appropriately.

Application of Hybrid Learning Approach in Teaching within Higher Education

Hybrid learning is an all-embracing approach made-up of the most established approaches found in both face-to-face and virtual learning with the aim of leading to an enjoyable learning experience [9]. In other words, Hybrid learning is about direct attendance of students within a learning session while others are able to participate via online from anywhere, they wish [10]. The Lecturers therefore engage students remotely as well as being able to apply the online tools for those students who have chosen to study virtually [11].

In Indonesia, because of the Covid 19 pandemic Disruption just like in other parts of the world, most institutions of higher learning either chose to go virtual or applied blended learning, and others decided to run a hybrid learning approach or model, where all lecturers were required to start making use of the learning digital technologies on a short notice [11], since face-to-face classroom student occupation capacity had been reduced to 50 percent. This move led to learning innovations; the figure below illustrates hybrid learning:

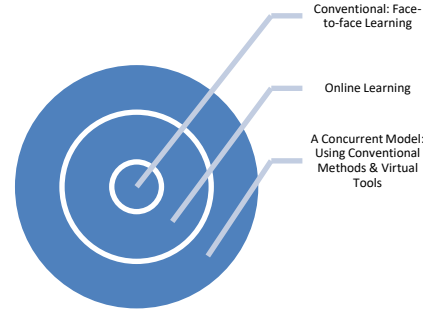

Figure 1: Shows a Hybrid Learning Model

As seen in figure 1 above, during the learning session, lecturers are able to facilitate face-to-face classes, while at the same time they are utilize the online learning tools which may, include zoom, teleconferencing and among others, enabling all students to participate either directly or physically [12]. In the effort to ensure critical thinking is developed among students, lectures are conducted through discussions,

question and answer sessions, brainstorming and problem solving [13], making use of the learning management system, which is also abbreviated as (LMS) used to facilitate remote learning.

Using Hybrid Learning Approach to Teach Mathematics Skills

Along with developments in the world of education, various innovative learning models and methods have been created and innovated to influence learning. Learning models innovated are intended for creating and emphasize understanding of concepts and how to apply technology using approaches like hybrid learning.

With its combined approach in teaching, hybrid learning brings together the most appropriate features from both the conventional teaching approaches blended with the online tools to ensure instruction is delivered to all learners in one session [14]. In the figure 2 below, an illustration of a hybrid learning approach in the teaching of mathematics is presented:

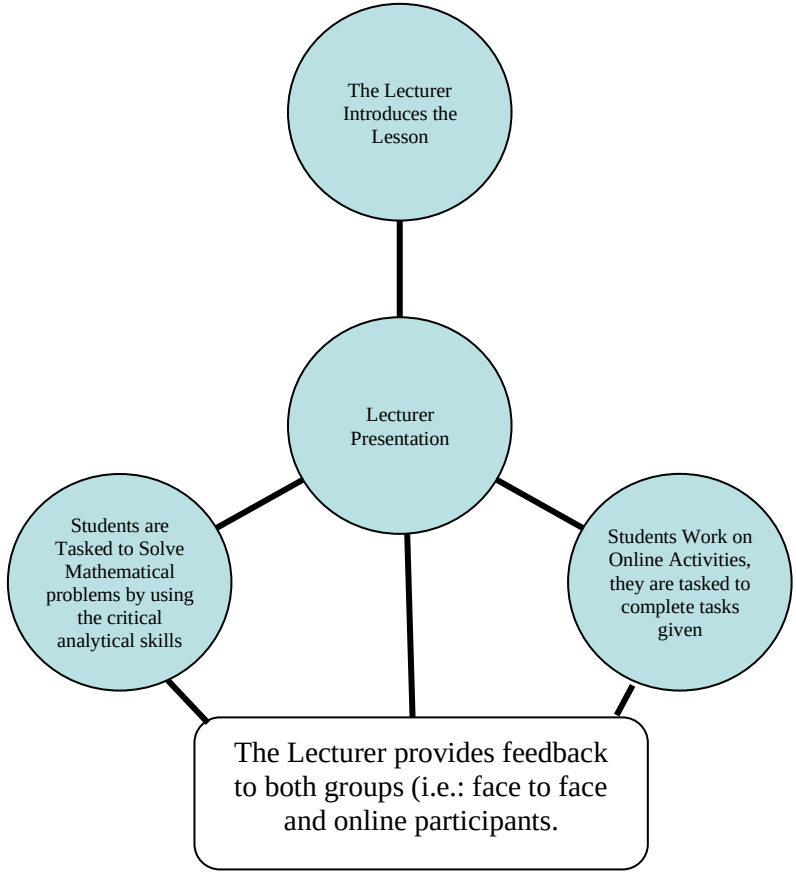

Figure 2: An Illustration of Hybrid Teaching of Mathematics

From the above figure 2, it is seen that in a hybrid learning and teaching approach, lecturers facilitate free interaction among students. This approach can be used to enhance students' skills,

including logical and critical thinking skills and also leads to understanding of content by each of the student.

Teaching Advanced Mathematics Skills to Enhance Students Critical Thinking Capabilities

There are many strategies capable of helping students improve their basic abilities [15], among such strategies is teaching Advanced Mathematical skills through enjoyable learning, such as hybrid learning, which allows students choose their own way of attending classroom session at their convenience, where learning technologies are effectively put to use more so in higher education. Su, Ricci and Mnatsakanian [16] have pointed out that reason, being logical and have valid information, leads to understanding of mathematics, which is an efficient approach in developing students critical thinking abilities.

Advanced Mathematical Thinking skills are skills that need to be possessed by students [17], especially those at university. Studies have revealed that students whose advanced mathematical thinking skills are adequate tend not to have difficulties in completing their education at a university which in practice [18] includes advanced mathematics courses and these advanced mathematical thinking skills supports the shaping of students' personality leaving them with qualities of being intelligent, critical, creative, empathetic to others, able to work together, confident, resilient and responsive to change [19].

Based on the above, this study used two indicators, namely: reading evidence and constructing evidence to help in identifying indicators which can enhance students critical thinking skills through the teaching of Advanced Mathematical Thinking Skills, the following table 1 summarizes the indicators:

Table 1: Shows the Indicators of Advanced Mathematical Thinking

Indicators	Explanation
Representation	• Reveal mathematical ideas • Communicating work results in a certain way as a result of interpretation of one's thoughts, such as: arithmetic symbol representation; language/verbal representation and image or graphic representation.
Abstract	• Generalize and generate/induce special forms in mathematical concepts to be able to identify similarities • Synthesize/combine parts of mathematical concepts to form a whole.
Mathematical Creative Thinking	• fluency: generates lots of ideas in various categories • originality (authenticity): have new ideas • elaboration (decomposition): solve the problem in detail
Developing Mathematical Proofs	• Construct proofs that have been obtained from mathematical concepts • Validating the evidence that has been obtained

Source: Personal Report and Analysis

From the table 1 above, there are three indicators suggested by the authors, that is representation, abstract, mathematical creative thinking and developing mathematical proofs. With representation, it helps to reveal ideas or concepts, while helping to influence communication and interpretation of these concepts. Abstract, is about using terms for either generalisation or looking at special concepts and ideas. Mathematical creativeness in thinking is about generating as many ideas as possible and being able to apply them to solve problems. And lastly, developing mathematical proofs, is all about constructing and reconstructing proofs through mathematical concepts and also validating them with evidence. Based on the description presented above, mathematical proof can be referred to as mathematical proofs which facilitate mathematical abilities used in reading mathematical concepts, symbols and constructing mathematical proofs.

Research Method

This this study aimed to see whether the application of hybrid learning approach in higher education through the teaching of Advanced Mathematical Thinking abilities could enhance students critical thinking abilities of prospective teacher students. Quantitative research methods can refer to research method that answers the formulation of a given research problem using quantitative techniques [20].

The design used in this study was a strong experimental research design with pretest-posttest control-group designs and using randomized designs. This design was chosen because it is in accordance with the research objectives which are to obtain an overview of the Advanced Mathematical Thinking Skills and how it enhances critical thinking abilities of prospective student teachers in the making received learning using hybrid learning models and conventional learning which are reviewed based on the basic abilities possessed by these prospective student teachers.

Apart from the above, in this study, we also aimed at examining how an increase in the ability of Advanced Mathematical Thinking skills and Enjoyment in learning Mathematics by the prospective student teachers were taught using a hybrid learning model, which was examined using observation and interview guides in the research process. This study applied *Befor-After* Research Design [21] (Christensen, Burke & Turner, 2015) to measure the basic abilities that research students have used pretest and posttest to measure Advanced Mathematical Thinking abilities that are formed after treatment. The table 2 below shows an illustration of the research design used in this study:

Table 2. An Illustration of a Research Design Before-After

Group	Basic skills (Pretest)	Treatment	Posttest
Experiment Group	×	×	×
Control Group	×	-	×

Explanation:
× = got the treatment
- = did not get the treatment

The Befor-After Research Design is a design with pretest and posttest to measure the increase [21] in Advanced Mathematical Thinking abilities after the treatment has been given to the research subjects. The hybrid learning approach was used on the experimental group, while the control group used conventional learning approaches.

Results

This research was carried out from early April 2020 to June 2022. The authors conducted a student's basic ability test (pretest) and continued with the treatment for over eleven times. After the treatment, in the twelfth phase, a post-test of Advanced Mathematics Thinking Abilities was carried out on prospective student teachers. The data was obtained by analyzing data following the sub-sections below:

Improvement of Advanced Mathematical Thinking Ability of the Prospective Student Teachers

The data collected in this study was data obtained from the results of distributing questionnaires. The questionnaires provided aimed to obtaining information about the students from a mathematics education study program within a university Bandung city. The students were mainly those attending lectures about multivariable calculus course. In the process, the authors conducted an analysis to establish whether the data obtained met the requirements for analysis using planned analysis techniques in accordance with the research objectives, analysis prerequisite tests were carried out using the MANOVA analysis technique.

The results of the normality assumption test on the Advanced Mathematical Thinking variable based on the Learning Method Factor obtained a

significance value greater than 0.05 ($p>0.05$), thus indicating a normal distribution. The results of the normality assumption test on the Advanced Mathematical Thinking ability variable based on the Basic Ability Factor obtained a significance value greater than 0.05 ($p>0.05$), hence showing a normal distribution.

The results of the description of the Advanced Mathematical Thinking variable based on the Learning Method Factor (i.e.: Hybrid learning treatment and conventional treatment) and Basic Ability factors (high Basic Ability and low Basic Ability). The results of the description of Advanced Mathematical Thinking based on the learning method factor obtained an average value of Advanced Mathematical Thinking in regarding to hybrid learning class of 48.1395 and in the conventional class of 32.8250.

The results of the description of Advanced Mathematical Thinking based on the interaction of learning method factors and basic ability factors obtained an average value of Advanced Mathematical Thinking in the hybrid learning class with high basic abilities of 49.2400 and those with low basic abilities of 47.0000. Then the average value of Advanced Mathematical Thinking in the conventional class with high basic ability is 34.9167 and with low basic ability is 30.6875.

Discussion

From the results of the study, it can be seen that there are significant differences and higher scores are seen in participants who studied using the hybrid learning approach. Because the hybrid learning approach, brings together the most appropriate features from both the conventional teaching approaches blended with the online tools to ensure instruction is delivered to all learners in one session [14].

This study proves that the hybrid learning method leads to better results regarding the learning of advanced mathematical thinking skills, since there was a difference in the performance of the prospective student teachers when the two groups were tested as seen above. This is because a hybrid learning model is an efficient learning approach which when applied to advanced mathematical thinking in accordance with existing theories, enhances students understanding of ideas and concepts with ease.

This maybe true due to the fact that approach ensures critical thinking is developed among students, because lectures are conducted through discussions, question and answer sessions, brainstorming and problem solving [13], hence giving the opportunity the students to think creative and there is a representation of varying ideas with limitations as it is conventional classes.

Conclusion

It is therefore concluded that from the results of the research above, it proves that there is a significant influence on the interaction of prospective student teachers after going through a hybrid learning interactive learning session, with a boost in abilities of the students. This is based on the average value of the results of advanced mathematical thinking abilities, which were obtained from students participating in the two groups that is the experiment group, using the hybrid learning approach, and control group, which used the conventional methods, with results lower in abilities. If well applied, advance mathematical thinking in accordance with existing theory, aims to improve the ability of prospective student teachers regarding problem solving. The concept also molds student teacher into creative educators, who are able to deal with problems and find solutions appropriate to those problems. The approach, has the capacity of the prospective student teachers into great thinkers, who are able to perform tasks systematically.

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