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Eksplorasi Kebutuhan Perkuliahan Kalkulus pada Kelas Kolaboratif: Apakah Integrasi Virtual Reality Berbasis Etnomatika Diperlukan?

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Abstrak

Kalkulus integral adalah salah satu mata kuliah yang cukup penting, tetapi justru menjadi fenomena masalah bagi mahasiswa, termasuk dalam perkuliahan yang dilakukan secara kolaboratif. Berbagai jenis penelitian dilakukan untuk mengkaji fenomena tersebut, salah satunya adalah fenomenologi. Tujuan penelitian ini adalah untuk menganalisis fenomena yang dialami mahasiswa pada perkuliahan kalkulus integral secara kolaboratif. Penelitian ini melibatkan dua ketua program studi, dua dosen, dan sembilan belas calon guru matematika dari program studi di Indramayu dan Mataram, Indonesia. Instrumen utama dalam penelitian ini adalah peneliti dengan beberapa instrumen tambahan, seperti lembar observasi program studi, pedoman wawancara dosen, dan angket mahasiswa. Data hasil penelitian dianalisis dengan menggunakan analisis tematik. Hasil penelitian mengungkapkan kendala dalam perkuliahan, seperti ketidaksiapan mahasiswa belajar online dan melakukan visualisasi, durasi video pembahasan yang singkat dan belum dikaitkan dengan dunia nyata, serta koneksi internet yang kurang stabil. Meskipun hasil pembelajaran kolaboratif belum lebih baik dari metode konvensional, terdapat beberapa kelebihan, seperti mahasiswa bisa memutar ulang video pembahasan materi dan mendapatkan kolega baru. Penelitian ini merekomendasikan agar perkuliahan kolaboratif dilakukan menggunakan *virtual reality* berbasis etnomatematika, memperbanyak video pembahasan materi, dan memperkuat materi prasyarat mahasiswa demi pemenuhan kebutuhan dalam perkuliahan kalkulus.

Kata Kunci: etnomatematika, kalkulus, *virtual reality*

Exploring the Needs of Calculus Lectures in Collaborative Classes: Is Ethnomatics-Based Virtual Reality Integration Necessary?

Abstract

Integral calculus is an important course, but it often becomes a problematic phenomenon for students, even in collaborative learning settings. Various types of research have been conducted to examine this phenomenon, one of which is phenomenology. The purpose of this study is to analyze the experiences of students in collaborative integral calculus courses. The study involved two program chairs, two lecturers, and nineteen prospective mathematics teachers from programs in Indramayu and Mataram, Indonesia. The main instrument in this study was the researcher, supported by additional tools such as program observation sheets, lecturer interview guides, and student questionnaires. The research data were analyzed using thematic analysis. The findings revealed several challenges in the course, such as students' lack of readiness for online learning and visualization, the short duration of discussion videos that were not yet linked to real-world contexts, and unstable internet connections. Although the outcomes of collaborative learning have not surpassed those of conventional methods, there are several advantages, such as students being able to replay discussion videos and gain new peers. This study recommends that collaborative learning should utilize virtual reality based on *ethnomathematics, increase the number of discussion videos, and strengthen students' prerequisite knowledge to better meet the needs in integral calculus courses.*

***Keywords**: calculus; ethnomathematics; virtual reality*

INTRODUCTION

Calculus is one of the compulsory courses that must be studied by prospective mathematics teachers in college (Hurdle et al., 2022). This course is considered important (Hammoudi & Grira, 2023; Husna & Hasibuan, 2018) because it is a gateway to learning higher mathematical concepts, especially functions and limits. In addition, calculus material is also usually used as a tool to study other disciplines, such as engineering, science, economics, and medicine (Kamid, 2012; Musyrifah, 2015). For example, some differential calculus concepts are used to predict the effects of changes in temperature, pressure, and humidity on the atmosphere. In the context of prospective mathematics teachers, studying calculus is one of the means for students to strengthen their content knowledge (Esposito & Moroney, 2020). Given the importance of calculus, ideally, students must have good competence in the course. However, research results in the last few decades provide different facts. Several previous studies (Deswita et al., 2021; Fatimah & Yerizon, 2019; Tall, 1992) reveal various problems experienced by students in learning calculus, such as low understanding of concepts, problem-solving abilities, and student learning motivation.

Tall (1992) reveals that dissatisfaction with calculus lectures appears in almost all parts of the world. Deswita et al. (2021) uses qualitative descriptive research to analyze the obstacles experienced by students in calculus lectures. The results of the study reveal that students experience didactic and epistemological obstacles. The didactic obstacles experienced are in the form of a limited understanding of concepts and errors in analyzing questions. Meanwhile, didactic constraints are in the form of inappropriate lecture method selection by lecturers. Susilo et al. (2023) uses an exploratory survey method to examine the difficulties experienced in integral calculus lectures. The results of the study reveal that there are around 21 types of difficulties in calculus lectures, with ten activities that can be used to overcome these difficulties.

Several studies described previously reveal the existence of obstacles in calculus lectures. However, there have not been many studies that use phenomenological designs in analyzing the obstacles experienced in calculus lectures, especially in integral calculus courses that are conducted collaboratively. The problems in calculus lectures have become a phenomenon that must receive special attention. Therefore, the purpose of this study is to analyze the phenomena experienced by students in integral calculus lectures collaboratively, especially those related to virtual reality (VR) and ethnomathematics. Collaborative lectures are conducted jointly between several universities (Scager et al., 2016). These lectures are classified as hybrid learning because they combine offline and online classes. This approach is chosen because it provides different experiences and perspectives for students (Scager et al., 2016; Wicaksono, 2024). Additionally, collaborative lectures integrate several technology platforms, with VR being one example. VR helps students visualize various complex shapes that are difficult to imagine. Meanwhile, ethnomathematics maintains the existence of culture in mathematics learning. To achieve the goal, the researcher has derived several research questions. Some of the research questions include: What are the obstacles experienced during collaborative integral calculus lectures?; What are the advantages of collaborative integral calculus lectures?; What are the learning outcomes of students in collaborative integral calculus lectures?; What are the suggestions for improvement for collaborative integral calculus?

METHOD

This study used a qualitative approach to answer several previous research questions. The research design used was phenomenology. This design was used because it tended to be able to explore various phenomena in life from various perspectives, either by an individual or a group of people (Iared et al., 2016; Isnawan et al., 2022; Laverty, 2003). The phenomenon in this study referred to the obstacles experienced by students. In this case, life was related to integral calculus lectures that were carried out collaboratively. While a group of people referred to the head of the study program, lecturers in charge of calculus courses, and students who had studied integral calculus, The collaborative lectures referred to in this study referred to the implementation of lectures that were carried out in a hybrid manner by combining online learning through LMS with face-to-face learning that was carried out online and offline. The LMS contained several videos discussing lecture material. The following was the LMS used: https://phytagoras.unwir.ac.id/. The procedure in this study then followed the following steps: preparation of instruments, data collection, data analysis, and interpretation of the data analysis results. In simple terms, the research procedure can be seen in Figure 1.

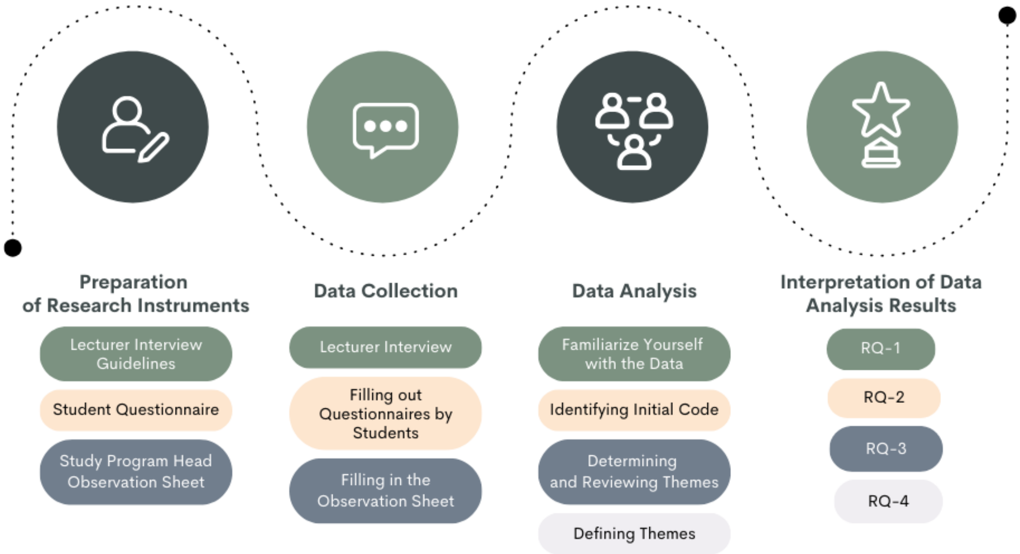

Figure 1. Research Procedure

This research was the result of the result of a collaborative effort between two private universities in Indonesia. One university was located in Indramayu, Indonesia, and the other was located in Mataram, Indonesia. The two universities were chosen because some students from both universities experienced problems in integral calculus lectures. In addition, both universities also had adequate facilities and infrastructure to carry out collaborative research. Both universities have often conducted collaborative online research in the last two years. Participants in this study consisted of three groups. First, two lecturers teaching calculus courses, aged 33–35 years, with 5–9 years of teaching experience as lecturers. Second, two heads of study programs, aged 32–35 years, with around 5–10 years of experience as lecturers. Third, nineteen prospective mathematics teachers had studied calculus, with an age range of 19 to 22 years, and the majority of them were female.

The main instrument in this study was the researcher because the approach used was qualitative (Creswell & Creswell, 2018). Meanwhile, some additional instruments in this study were interview guidelines for calculus lecturers (IG), student questionnaires (SQ), and observation sheets for the heads of study programs (OS). Interview data can then be accessed on the following page: https://shorturl.asia/dHsqx. Student questionnaire distribution data can be accessed on the following page: https://shorturl.asia/i53K1. Meanwhile, observation data between the two study programs can be accessed on the following page: https://shorturl.asia/aZc5V. The data obtained were then analyzed using thematic analysis. Several steps in thematic analysis were carried out, including reading the data repeatedly to familiarize oneself with the data; identifying the initial codes from familiarizing oneself with the data; determining the themes from the initial codes; reviewing the themes with the initial codes that formed them; and naming or defining the themes (Isnawan et al., 2023; Nowell et al., 2017). These themes ultimately referred to various needs, such as obstacles, advantages, learning outcomes, and suggestions for improvement for collaborative integral calculus lectures.

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RESULTS

What are the obstacles experienced during collaborative integral calculus lectures?

Based on the results of the thematic analysis, information was obtained indicating six themes that were obstacles during collaborative integral calculus lectures. The first theme was that students were not ready to learn online. The second theme identified was that the video discussion of the material contained in the LMS was too short. Third, the lecture material had not been linked to the real-world context. Fourth, the internet signal was unstable, causing disruptions. Fifth, students had difficulty visualizing the material. Lastly, poor lecture schedule management was identified as a significant obstacle. These six themes were derived from several initial codes originating from various data sources. Table 1 shows the initial codes that formed the six themes described previously.

Table 1. Initial Codes of Theme 1 (T1)

Initial Code	Data Source	Theme
Students are on the road.	IG-A	Students are not ready to learn online.
Students are in the hospital.	IG-A	
There are exchange students.	IG-A	
Students are not detected.	IG-A	
Students are not ready to learn.	IG-A	
Students are not interested in learning.	IG-A	
Students assume that they will not understand if they learn online.	IG-B	
Seven students prefer offline learning.	SQ	
The video discussing the material in the LMS is too short.	IG-A	The video discussing the material contained in the LMS is too short.
The video is too short, so it does not cover all the material.	IG-B	
The questions used are ordinary.	IG-A	The lecture material has not been linked to a real-world context.
The questions have not been linked to everyday life.	IG-B	
The internet signal is not good because not all students live in the city.	IG-B	The internet signal is not stable.
Six students are constrained by the internet network.	SQ	
Students have difficulty visualizing area and volume.	IG-A	Students have difficulty visualizing.
Study time is too late in Mataram.	IG-B	Poor management of lecture schedules.

What are the advantages of collaborative integral calculus lectures?

The results of the thematic analysis revealed that there were two themes: students could replay the video of the material discussion (T2-1) and had new colleagues (T2-2). Several initial codes that formed the two themes can be seen in Table 2.

Table 2. Initial Codes of Theme 2 (T2)

Initial Code	Data Source	Theme
The video can be repeated.	IG-A	Students can replay the video of the material discussion.
The video can be repeated.	IG-B	
The results are slightly better because of the new atmosphere, new friends, and new enthusiasm. The video can be repeated.	IG-B	
The results are slightly better because of the new atmosphere, new friends, and new enthusiasm. The video can be repeated.	IG-B	Students have new colleagues.
Ten students agree that collaborative learning is fun because there are new friends and lecturers.	SQ	

What are the learning outcomes of students in collaborative integral calculus lectures?

Based on the results of the thematic analysis, information was obtained that there was only one theme related to the advantages of collaborative lectures, namely that there was no significant difference between collaborative lectures and regular lectures (T3). This theme was formed from two initial codes, as shown in Table 3.

Table 3. Initial Codes of Theme 3 (T3)

Initial Code	Data Source	Theme
The difference is not clear.	IG-A	There is no significant difference between collaborative lectures and regular lectures.
There is no difference between face-to-face.	IG-A	
The results are slightly better because of the new atmosphere, new friends, new enthusiasm, and videos that can be repeated.	IG-B	

What are the suggestions for improvement for collaborative integral calculus lectures?

In this context, four themes are formed after thematic analysis. First, the use of virtual reality (VR) in lectures (T4-1). Second, linking lecture materials with ethnomathematics (T4-2). Third, extend the duration of the video discussion of the material (T4-3). Fourth, strengthen the prerequisite material for students, especially in visualizing the Cartesian coordinate form of the object being viewed (T4–4). Table 4 shows some initial codes that form the theme.

Table 4. Initial Codes of Theme 4 (T4)

Initial Code	Data Source	Theme
VR seems useful as long as it fits the content.	IG-A	Use of VR in lectures.
VR seems to attract students' interest and motivation to learn because it's like being in a cinema.	IG-A	
Media that helps visualization.	IG-A	
VR will greatly help students' thinking processes.	IG-B	
It can be about everyday or ethnomathematics problems, but the foundation must be strong.	IG-A	Linking lecture materials with ethnomathematics.
Relating everyday material to volume and area.	IG-B	
Extending the duration of the video.	IG-A	Extending the duration of video discussions of the material.
Students must at least be able to represent Cartesian coordinates on objects they see.	IG-A	Strengthening students' prerequisite materials, especially in visualizing the Cartesian coordinate form of the objects being viewed.

These various suggestions for improvement also seemed to be able to be implemented in both study programs for several reasons. Based on the results of the study program readiness questionnaire filled out by both study programs, information was obtained that supported the previous suggestions for improvement. First, there were good technological support resources in both study programs, such as all students having smartphones; classrooms having LCD projectors, *wifi*, and electricity networks; and a mathematics laboratory complete with VR glasses. Second, there were representative, comfortable, and safe classes, with support for group learning. Third, the two lecturers who taught integral calculus courses were lecturers who had quite a long experience teaching the course and were able to apply the latest technology well. Fourth, the distribution of integral calculus courses between the two study programs was the same, namely discussing area and volume. The first and second reasons strengthened T4-1, the fourth reason strengthened T4-2 and T4-3, and the third reason strengthened T4-4.

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DISCUSSION

As previously described, six themes are obstacles during collaborative integral calculus lectures. One of them is that students are not ready to learn online (T1–1). This theme is formed by several initial codes, such as students' lack of intention to learn, the assumption that students do not understand how to learn online, and some students preferring to learn offline. The results of this study are in line with research conducted by Pulungan et al. (2022), which revealed that 86,4% of participants in the study wanted mathematics learning to be done offline. In addition, the study also revealed that students have low interest and motivation to learn and have difficulty adapting to online learning. In contrast to the results of this study, Ratnadewi (2021) revealed that students tend to be quite ready to learn online. This is because most students have supporting facilities and infrastructure for online mathematics learning, and the conditions at that time required online learning.

Related to theme T1-2, participants in this study considered that the next obstacle in collaborative lectures was the duration of the video discussion of the material contained in the LMS, which was too short. The video presented was about 10 minutes long. The duration of the video is considered optimal. Demir and Birgili (2024) stated that 10 minutes is the optimal duration for a learning video. However, Hamid and Samad (2015) stated that there is no direct relationship between video duration and student viewing time. The study revealed that long videos have longer viewing times than shorter videos. Regarding video duration, lecturer participants should use several criteria in making lecture videos, such as choosing basic concepts, main concepts, or difficult concepts as topics in learning videos.

The next obstacle is the lecture material that has not been linked to the real-world context (T1-3). This obstacle is then classified as an urgent obstacle to get attention. This is because one of the goals of integral calculus lectures in higher education is to help solve real-world context problems using the integral calculus concepts studied (Irvan, 2024). How can real-world problems be solved when it turns out that the mathematics lectures that students take are not relevant to the problem? If we refer to Awaludin et al. (2020), it was found that problem-based integral calculus lectures are more effective than conventional lectures. The use of various forms of visuals, such as images, videos, and animations, is quite helpful for students in integral calculus lectures.

T1-4 (unstable internet signal) is the next obstacle experienced in collaborative lectures. This obstacle is classified as one that is usually experienced in online learning. Fadhilah and Husin (2023) expressed something in line with the fact with the fact that one of the obstacles to online lectures in universities is the existence of internet quotas and unstable internet signals. Isnawan et al. (2023)also revealed that unstable internet signals are usually experienced in online learning. Moreover, when online learning involves students who are in rural areas with poor internet quality. Poor lecture schedule management (T1–5) is the last obstacle experienced in this study. Considering that the two study programs that participated in this study are in different time zones, scheduling problems are a fairly reasonable problem for students to experience. The results of this study are related to research conducted by Sivunen et al. (2016), which revealed that differences in time zones play an important role in a job.

In addition to experiencing challenges, collaborative lectures also have advantages. As described in the previous section, it was found that there are two advantages to collaborative lectures: students can replay the video discussion of the material (T2-1) and have new colleagues (T2-2). T2-1 is considered an advantage because it can be a flexible learning resource for students. Because the discussion of the material is contained in the video, students will easily replay the video if they have difficulty understanding the lecture material. In the long term, video-based learning also trains individuals to become accustomed to learning in any condition, situation, or at any time (Hegeman, 2015; Insorio et al., 2023). Unlike offline lectures, students cannot ask the lecturer again to explain, especially after the lecture activity takes place. The results of this study are then in line with Kinnari-Korpela (2015), who stated that the use of short videos in learning integral calculus is quite meaningful because it can help students after the lecture. Students can replay the video when they encounter obstacles related to the material being studied. In line with previous research, Insorio et al. (2023) also stated that the existence of discussion videos provides an opportunity for students to repeat explanations related to the material individually. The results of other studies by Hegeman (2015) also revealed the same thing: redesigning lectures by integrating videos had better performance in algebra lectures.

Getting new colleagues (T2-2) is the next advantage of collaborative lectures. This then makes the lecture vibe more interesting. The results of this study are then in line with Wicaksono (2024), who stated that collaborative learning can increase student involvement and motivation in lectures. However, collaborative learning must also continue to be adjusted to the times. For example, the collaboration that occurs is not only with students in one college but also with students at other colleges. This is in line with what was conveyed by (Scager et al. 2016) that collaborative lectures need to be redesigned by using various challenging tasks that are relevant to the common interests of students.

Take another look at Table 3. Based on the table, it was found that there is no significant difference between collaborative lectures and regular lectures. The results of this study do not seem to be able to be used as findings because the basis used is still limited to interview data. To see the difference in learning outcomes, researchers can use various types of statistical tests, such as N-gain or t-tests (Isnawan, 2023). However, this study does not discuss this and will be discussed on another occasion.

Regarding suggestions for improvement, the results of the thematic analysis revealed that there were four recommendations by lecturers teaching collaborative integral calculus courses. First, the use of VR in lectures (T4-1). Lecturer participants said that the use of VR in lectures was considered to be able to attract students' interest in learning and help students' thinking processes, especially in visualizing. The results of this study are supported by the theory expressed by Putman and Id-Deen (2019), who considers that VR can make mathematical concepts more exciting and interesting for students to learn. Kaufmann (2009) also stated that VR technology is quite interesting and motivating for learning mathematics. Examples of using VR in lectures can be seen in Figure 2.

Figure 2. Example of Using VR in Hyperboloid Visualization (Kaufmann, 2009: 140)

Second, T4-2 (linking lecture material with ethnomathematics). Participants considered that the use of ethnomathematics could be a solution to make integral calculus lectures more relevant to real-world contexts. The results of this study are supported by research conducted by Tampubolon et al. (2023), which revealed that the application of ethnomathematics can improve students' understanding of mathematical concepts. Turmuzi et al. (2023) revealed that ethnomathematics can make students' memory and mathematical achievement better than regular learning. Supriadi (2019) also revealed that ethnomathematics-based didactic design can optimize students' mathematical thinking skills. Figure 3 shows an example of the use of the traditional *Sundanese Engklek* game in mathematics learning.

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Figure 3. Traditional *Sundanese Engklek* Game in Mathematics Learning (Supriadi, 2019)

The third suggestion is to extend the duration of the discussion video (T4-3). This suggestion seems impossible to implement fully. In other words, the duration of the learning video in the previous collaborative lecture was optimal, which was 10 minutes (Demir & Birgili, 2024). However, a solution that can still be considered is to increase the number of discussion videos with a maximum duration of 10 minutes. This solution is considered rational because the lecturer participants considered that the video duration was too short. After all, it could not accommodate all the lecture material. Therefore, a more relevant solution is to increase the number of discussion videos with the same duration.

Strengthening students' prerequisite materials, especially in visualizing the Cartesian coordinate form of the object being viewed (T4–4), then became the last suggestion from the participants for improving the lecture. This suggestion seems quite relevant because mastering the prerequisite material well is one of the determinants of success in mathematics lectures. The results of this study were then supported by Mokry (2016), who revealed that one of the determinants of success in Calculus 2 lectures is good mastery of prerequisite material. The same results were also expressed by Fatimah and Yerizon (2019), who considered that one of the obstacles experienced by students in calculus lectures was the low mastery of prerequisite material, such as creating and analyzing elements in the graph of the function and doing trigonometry. Finally, all of these suggestions are then relevant and supported by the conditions that exist in both study programs, such as sources of content or materials, conditions of technological resources, learning facilities, and lecturer resources at each university.

CONCLUSION

Based on the previous description, several findings can be drawn. First, there are several obstacles experienced during collaborative integral calculus lectures, such as students not being ready to learn online, the video discussion of the material is too short, the content of the lecture material not being linked to the real-world context, the internet signal being unstable, students having difficulty visualizing, and poor lecture schedule management. The advantages of collaborative lectures are that students can replay the video discussion of the material and meet new colleagues. However, the results of collaborative lectures cannot be said to be better than conventional lectures because there has been no more in-depth testing on this matter.

Finally, this study recommends that collaborative lectures use VR, integrate ethnomathematics, increase the number of 10-minute video discussions of the material, and strengthen students' prerequisite materials. Based on these findings, this study recommends that subsequent researchers study several things. First, study in depth the impact of collaborative learning on the development of student competencies. Second, redesign collaborative lectures by utilizing VR technology based on ethnomathematics. Third, provide special treatment to optimize students' prerequisite abilities before starting integral calculus lectures. These recommendations are then expected to optimize students' mathematical competence, especially in integral calculus courses. With the optimization of mathematical competence, students as prospective mathematics teachers are expected to have good content knowledge, which will have a direct impact on improving students' mathematical competence in schools.

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