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Article 2

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The Application of Synchronous and Asynchronous Learning using E-learning on Elementary Linear Algebra

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Abstract. *Learning activities were changed from face-to-face to full-online due to the COVID-19 pandemic at the end of 2019. Online learning through WhatsApp Group (WAG) was used by a mathematics teacher in higher education program in the early 2020. However, the learning result showed that 75% of preservice teacher were unable to accomplish their elementary linear algebra material. The combination of online learning through asynchronous method and synchronous learning was an alternative solution to solve the problem and enable preservice teachers having virtual face-to-face interactions with their lecturers. Therefore, this study was conducted to determine the improvement in preservice teachers' learning outcomes and responses to synchronous and asynchronous learning. The research design used was one group posttest-only with 23 subjects were selected by clustered random sampling. Data were analyzed by descriptive statistical analysis. The test results showed that learning outcomes after synchronous and asynchronous learning was effective. While the questionnaire results expressed most preservice teachers gave a positive response to both learning methods. Thus, the combination of the two methods could improve the effectiveness of online learning during the Covid-19 pandemic. It is recommended that higher education institutions provide innovative e-learning platforms for preservice teachers in developing further online learning methods.*

Keywords*: synchronous learning, asynchronous learning, e-learning, preservice teacher, elementary linear algebra*

Introduction

The emergence of a new coronavirus called Novel Corona Virus (2019-nCoV) at the end of 2019 shook the world. The virus was originally discovered in Wuhan China in December 2019 and later spread significantly to all countries, including Indonesia, in early 2020. The pandemic had a big impact on different sectors of the country including health, economy, and education. This is observed from the fact that educational institutions ranging from kindergarten to universities were restricted from using face-to-face learning in order to reduce personal contact. Moreover, Azhari & Fajri (2020) also showed that the government enforced policies directed toward closing classrooms without stopping learning activities, thereby leading to the implementation of distance learning by schools. This led to the transition from face-to-face to online learning methods through the use of different information technologies (Rehman & Fatima, 2021).

WhatsApp Group (WAG) online learning was implemented at STKIP PGRI Bangkalan in early 2020 but this method was observed to have several shortcomings, specifically in the process of teaching elementary linear algebra. It was discovered that 75% of preservice teachers were unable to complete their study while only 20% completed. This is considered to be a significant reduction in comparison with the 86% who completed their studies as reported in previous studies conducted on the effectiveness of learning in an elementary linear algebra course (Sari, 2016).

Elementary linear algebra is a basic course required to be passed by students because it is a prerequisite for further courses such as abstract algebra. Suryaningsih (2016) & Ruswana (2019) also showed that it is a basic subject needed to be mastered by low-level students due to its ability to make learning other subjects easier. Thus, preservice teachers must to master all material of elementary linear algebra.

This background information shows that there is a need to change the online learning approach. This can be achieved through the implementation of asynchronous learning which was explained by Skylar (2009) to be capable of providing students with a flexible and self-paced environment they need to access course content using different tools. This is due to the fact that students are not usually restricted to a set day or time for communication, but allowed more time to prepare a response to a set of directions or questions. Asynchronous learning is usually implemented through a university's e-learning Moodle platform. Meanwhile, e-learning is defined by Hambrecht (in Ogbonna, et.al, 2019) to be a generic term covering a wide range of ICT technology-based applications and processes including computer-based learning, web-based learning, virtual classrooms, digital collaboration, and networking. It normally contains the content for one semester such as the materials, discussion forums, and assignments and its use has been reported by Yuhasriyati, et.al (2020) to have the ability to force educational processes to run faster in terms of accessibility and quality. It is also very influential on the learning activities and outcomes for students (Fitriani & Nurjannah, 2019) with the application of blended learning through Moodle platform reported to have received positive feedback from students studying mathematics (Lin, et.al, 2017).

Blended learning which involves the combination of e-learning and direct face-to-face learning is the norm before the pandemic and this method has been reported in several studies to have the ability of improving students' learning outcomes. For example, Lin, et.al (2017) conducted ANCOVA and MANCOVA analyses and showed that blended learning benefitted students in the experimental group by having a positive effect on their learning outcomes and attitudes toward studying mathematics in a blended environment. These results are in line with

Sukma & Priatna (2020) that the implementation of blended learning was able to improve students' critical thinking skills (CTS).

Learning activities were conducted fully online during the pandemic (Trenholm & Peschke, 2020) and this indicates the use of e-learning without face-to-face interaction. This means synchronous learning is perceived to be an alternative to virtual face-to-face learning between lecturer and students. This was further explained by Shi & Morrow in Skylar (2009) that the instructor leads the learning while all learners log in simultaneously and communicate directly with each other in real-time.

STKIP PGRI Bangkalan implemented synchronous learning through Zoom, Google Meet, and others to ensure students understand learning materials effectively and produce adequate outcomes. This is in line with the findings of Aisyah and Sari (2021) that the use of the Google Meet platform was able to improve students learning outcomes. This means through asynchronous learning through e-learning combined with synchronous learning through the virtual conference is an alternative method to teach elementary linear algebra in the school. Several studies showed the success of this combined method as indicated by its ability to increase the cognitive academic achievements of students studying word processing as reported by Ogbonna, et.al (2019).

The college also implemented a policy considered to be related to online learning in the middle of 2020, which in the form of asynchronous and synchronous. However, the synchronous learning was applied for 7-8 meetings through webinar classes such as Zoom, Google Meet, and others while asynchronous was fully used for 14-16 meetings through e-learning platforms. It lines with study of Mairing, et.al (2021) that the implementation of asynchronous and synchronous online learning approaches was effective in improving students' learning outcomes and skills of using Microsoft Excel during the Covid-19 pandemic. The effectiveness as indicated by the average of the outcomes was more than 75 (scale 0-100), and the skills were increased 1 level higher (scale 1-5). Furthermore, the students positively responded toward the approaches. So that, the implementation of asynchronous and synchronous online learning can build learning effectiveness during the Covid-19 pandemic at STKIP PGRI Bangkalan.

There is a need to evaluate the effectiveness of this method and this can be achieved through the perspectives of preservice teachers considered the learning objects. Therefore, this study was conducted to determine the improvement of preservice teachers' learning outcomes based on the combination of synchronous and asynchronous learning to elementary linear algebra; and their responses to the learning method.

Method

Treatment was applied to the participant's group to determine the effect of synchronous and asynchronous learning conducted on the outcome and responses of preservice teachers. Asynchronous learning was applied in the form of e-learning classes on the university Moodle while synchronous was in the form of webinar classes on Zoom. The learning effectiveness was determined through tests and a list of questions presented through instruments provided to the participants. It is important to note that the treatment was applied in a class and this means this is an experimental study with a one-group posttest-only design.

The population includes all 34 preservice teachers in the mathematics education study program at one of Universities in Bangkalan, Indonesia during the odd semester of the 2021/2022 academic year while a total of 23 were selected as samples using clustered random sampling technique. It was done by clustering male and female participants. Afterward, from 14 males and 20 females it was chosen 8 males and 15 females randomly. The sample was heterogeneous based on gender and initial mathematical ability determined through their calculus scores in the previous semester.

Study instruments include mid-test, final-test, and questionnaire. The lesson plan consists of 16 meetings with eight conducted through e-learning and Zoom webinar classes in the 2^{nd}, 4^{th}, 6^{th}, 8^{th}, 10^{th}, 12^{th}, 14^{th}, and 16^{th} meetings while the remaining were through e-learning and WhatsApp Group (WAG) at the 1^{st}, 3^{rd}, 5^{th}, 7^{th}, 9^{th}, 11^{th}, 13^{th}, and 15^{th} meetings. It is important to note that 8 webinar classes were conducted in line with the rules of the campus in relation to synchronous learning due to constraints in purchasing internet quota. The mid-test provided to students at the 8^{th} meeting and the final test at the 16^{th} meeting were conducted through e-learning and Zoom webinar classes. The questions were developed according to the material in the lesson plan and the tests were made valid through construct, content, and face validities such that the construct aspect was implemented by ensuring the results of both tests were able to measure the abilities of preservice teachers in elementary linear algebra without focusing on other variables. The content aspect involved the review and development of grids that covered questions and related indicators without missing any as indicated in Tables 1 and 2 for mid and final tests respectively. Meanwhile, the face validity was conducted by two experts with the focus on the evaluation of the elements for the truth concept, rules to prepare the questions, symbols and mathematical formulas, punctuation marks, pictures, and language. The results showed that the average face validation value for the mid-test was 4.17 and the final test had 4.33, thereby indicating they were both valid to be used.

Table 1. Mid-test grid (duration 90 minutes)

No	Indicators	Learning Domain			Level	Learning Material	Question Number	Max Score
		C	A	P				
1	Given several equations, students determine whether they are linear equations or not	√			C2	System of linear equations and Linear equation	1	10
2	Students can make the system of linear equations with 3 equations and 5 variables	√			C2	System of linear equations	2	10
3	Given several matrices, students can determine row echelon matrix, reduced row echelon matrix, or none of the two.	√			C2	Matrix	3	10
4	Given the system of linear equations, students can solve the system of linear equations using Gauss Jordan elimination	√			C3	Gauss Jordan Elimination	4	15
5	Given the system of linear equations, students can determine the coefficient value of one linear equation to ensure the system a) has no solution, b) has one solution, and c) has many solutions	√			C3	Solving system of linear equations	5	20
6	Given 2 matrices, students can determine the operation result of two matrices	√			C2	Matrix operation	6	10
7	Given a matrix, students can determine an inverse matrix using the inverse algorithm	√			C2	Inverse matrix	7	15
8	Given several matrices, students can determine the upper triangular matrix, lower triangular matrix, and diagonal matrix	√			C2	Matrix	8	10

Table 2. Final test grid (duration 90 minutes)

No	Indicators	Learning Domain			Level	Learning Material	Question Number	Max Score
		C	A	P				
1	Given a matrix, students can determine the matrix determinant using cofactor expansion	√			C3	Cofactor Expansion	1	10
2	Given a system of linear equations, students can solve the system using Crammers' rules	√			C3	Crammers' rules	2	10
3	Given three sets, students can prove that three sets are vector spaces or not	√			C4	Vector Spaces	3	15
4	Given three pairs of W and V sets, students can prove whether set V is a subspace of set W	√			C4	Subspace	4	15
5	Given a set S and four vectors, students determine whether four vectors are linear combinations of vectors in set S	√			C3	Linear combinations	5	10
6	Given three sets, students determine that they are linearly independent or linearly dependent on R^3 or $M_{2,2}$	√			C3	Linearly independent and linearly dependent	6	15

7	Given several sets S, students can show that these sets are not the basis of R^3	√	C3	Basis	7	15
8	Given a set S, students can show the basis S of $M_{2,2}$ and determine the dimensions of the S subspace of $M_{2,2}$	√	C3	Basis and dimension	8	10

A questionnaire was developed to measure the responses of preservice teachers to the combined approach. The validity of the questionnaire was also determined through construct, content, and face validities such that the construct aspect focused on ensuring its results actually measure the teachers' response to synchronous and asynchronous learning. The content aspect also involved reviewing and making questionnaire grids to cover questions and related indicators without missing any as indicated in Table 3. Meanwhile, the face validity was conducted by two experts through the evaluation of the concept truth elements, rules to write the questions, and displays for language. The results showed that the average face validation value for the questionnaire was 4.83. It is important to note that the responses to the statements on the questionnaire were designed to be provided through a Likert scale.

Table 3. Aspects and indicators of the questionnaire

No	Aspects	Indicators	Statements
1.	Knowledge	Students can understand elementary linear algebra material	Students' knowledge of elementary linear algebra material through online learning
			Students' ability to understand every elementary linear algebra material through online learning
			Students' ability to solve problems related to elementary linear algebra material through online learning
2.	Attitude	Students are active in asynchronous and synchronous learning	Students' attitude while learning independently through the resources in e-learning
			Students' attitude while responding to discussion forums
			Students' attitude while downloading assignments, solving, and uploading the answers in e-learning
			Students' attitudes about taking synchronous learning
			Student attitude while discussing through webinar classes
			Frequency of students accessing e-learning
3.	E-learning and Webinar classes applications	Ease of access and usefulness for students	Ease of accessing the e-learning platform
			Ease of accessing the webinar class platform
			The usefulness of accessing the e-learning platform
			The usefulness of accessing the webinar class platform

Data were collected using tests and questionnaires provided online through e-learning and Google form. There are two tests were conducted; mid test in eighth meeting and final test in sixteenth meeting. Meanwhile the questionnaire was once administered in sixteenth meeting. The learning itself was implemented asynchronously and synchronously as indicated in the lesson plan design. Data were analyzed using descriptive statistical analysis because the aim was not to generate data but explain and provide an overview of the characteristics of a data series. The processes involved are stated as follows:

1. Analysis of Mid-Test and Final Test

   The data from the test were measured using a completeness test which includes individual and classical. Meanwhile, the Ministry of Education and Culture categorizes subjects' scores into 5 groups as follows:

   $0 \leq$ score < 35 : very low
   $35 \leq$ score < 55 : low
   $55 \leq$ score < 65 : medium
   $65 \leq$ score < 85 : high
   $85 \leq$ score ≤ 100 : very high

   Widoyoko (2009) also determined the classical completeness criteria as follows:

   $p > 80$: very good
   $60 < p \leq 80$: good
   $40 < p \leq 60$: quite
   $20 < p \leq 40$: less
   $p \leq 20$: very less

   This information was used to establish the criteria for individual completeness by setting a score of 65% as the threshold for the completion of learning by preservice teachers, while the classical completeness criterion is when 80% have completed their studies.

   The implementation of asynchronous and synchronous online learning approaches was effective, if the classical completeness criterion, mid and final test results were achieved.

2. Analysis of Questionnaire Data

   The questionnaires responses were classified into two, including the questions with 4 answers in the form of 1, 2, 3, 4 and with 2 answers such as Yes and No.

   For the first questions, the criteria are as follows:

   1, 00 $\leq$ average $<$ 1, 50: less
   1, 50 $\leq$ average $<$ 2, 50: enough
   2, 50 $\leq$ average $<$ 3, 50: good
   3, 50 $\leq$ average $\leq$ 4, 00: very good

   The responses were believed to be positive when they are in good and very good categories.

   For the second questions, the responses were believed to be positive when more than 50% are good.

Results and Discussion

Asynchronous and synchronous learning activities

The first set of data was collected on Tuesday, October 5, 2021, according to the class schedule with the lecturer observed to have filled the required e-learning content such as the introductory session, 1st–7th, 9th–15th, 8th, and 16th sessions before the class started. The introductory session contains 1) an explanation of course descriptions, 2) course achievements, 3) an introduction forum (lecturer introduction video), 4) lecture contracts, 5) libraries, and 6) an attendance list. The contents in the 1st–

7th and 9th–15th sessions include 1) greetings and explanations, 2) learning achievements, 3) learning materials, 4) discussion forums, 5) assignments, and 6) links to webinar class meetings while the 8th and 16th sessions were 1) greetings and explanations sessions and 2) mid-test or final-test questions according to the specified format. The display of the e-learning platform is presented in Figures 1, 2, and 3, the discussion and closing sessions are indicated in Figures 4 and 5, and the discussion sessions conducted on WAG in Figure 6.

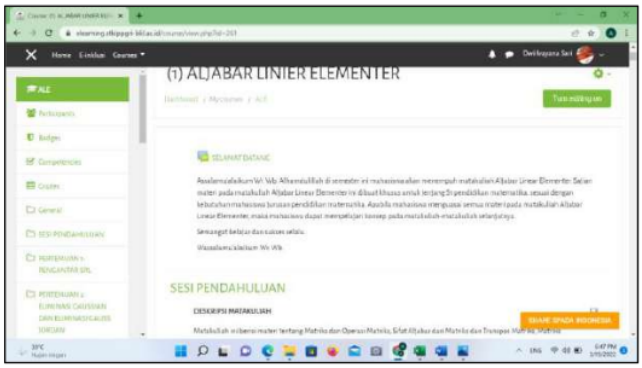

Figure 1. Front view of elementary linear algebra in e-learning

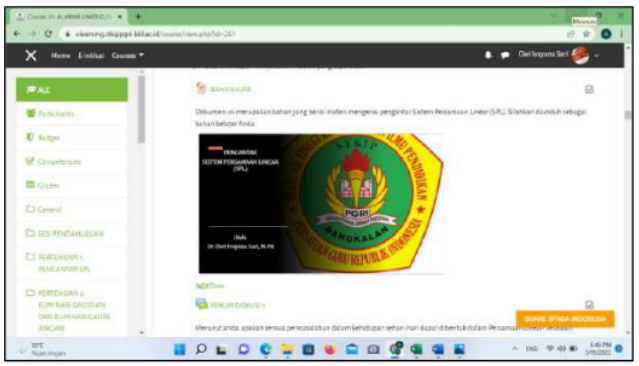
Figure 2. Content display at 1st meeting in e-learning

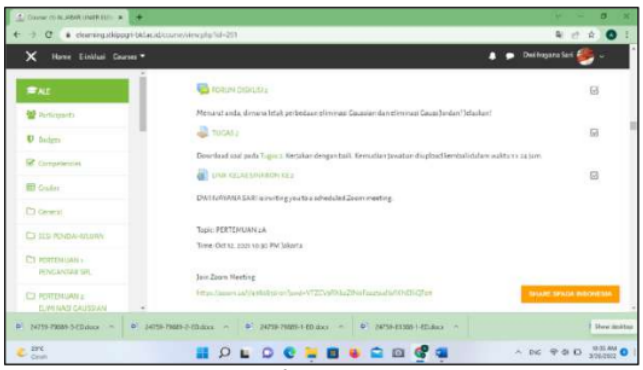
Figure 3. Content display at 2nd meeting in e-learning

Figure 4. Discussion session in the webinar class (zoom)

Figure 5. Closing session in the webinar class (zoom)

Figure 6. Discussion session in WAG

The first meeting was conducted asynchronously through e-learning classes with preservice teachers observed to have filled the attendance lists, accessed contents, studied teaching materials,

responded to discussion forums, did assignments, and uploaded answers to the e-learning platform. Meanwhile, synchronous learning was conducted through WAG to provide teachers the opportunities to ask questions on the parts they did not understand from 10.30 - 13.00.

The second meeting was implemented synchronously through a webinar class using the Zoom application and preservice teachers filled the attendance list in e-learning after which lecturers explained the material using PowerPoint and video. They were allowed to ask questions and answer directly followed by discussions on the application. The activity was continued asynchronously through the e-learning platform where they downloaded tasks and uploaded answers. These learning activities were continued in the 4^{th}, 5^{th}, 6^{th}, and 7^{th} meetings and followed by a mid-test conducted synchronously through a webinar class in the 8^{th} meeting after the questions have been previously downloaded from the e-learning platform.

Data collection was continued from the 9^{th} to 15^{th} meetings with the learning activities observed to have been implemented synchronously and asynchronously such previous. The final test was conducted at the 16^{th} meeting synchronously through the webinar class after the questions have been downloaded from the e-learning platform.

Learning outcomes and their improvement for preservice teachers

The mid-test results showed that 17 of 23 preservice teachers had more than 65% of the total score. This means 87% have completed the study. It indicated that the learning outcomes of elementary linear algebra after it was taught through the combination of synchronous and asynchronous learning was effective. Moreover, the final test results showed that all preservice teachers achieved more than 65% of the total score and this further confirms that the learning outcome was effective.

These findings showed that the learning outcomes of preservice teachers in elementary linear algebra increased due to the application of the combined method. This is in line with the results of Zaharah, et.al (2020) that the application of e-learning introduced progress and innovation to education in Indonesia as indicated by almost 75% of students who participated in online learning simultaneously during the Covid-19 pandemic. Moreover, Sindu & Paramartha (2018) showed that the use of instructional media such as video and slide synchronization systems theoretically facilitated the learning ability of students during material discussion and also made the instructional time more effective. This means the combination of synchronous and asynchronous learning is one of the solutions for the challenges observed in online learning activities during the pandemic.

Preservice teachers' responses

Preservice teachers were asked to fill out a questionnaire after the class and the responses are made available on google Forms in the link:

https://bit.ly/ANGKET_MAHASISWA_TERHADAP_PEMBELAJARAN_ALIN while the results related to the knowledge aspect are presented in the following Table 4.

Table 4. Responses to the knowledge aspect

No	Statements in the questionnaire	The number of preservice teachers' responses in each category (n)				Total respondents	Analysis result					
		less (1)	enough (2)	good (3)	very good (4)		$n \times 1$	$n \times 2$	$n \times 3$	$n \times 4$	Average	Category
1	My knowledge of elementary linear algebra is very good	3	5	10	5	23	3	10	30	20	3	Good
2	I can explain the meaning of the linear equation system	0	4	11	8	23	0	8	33	32	3	Good
3	I can explain the Gauss Jordan elimination method	0	4	11	8	23	0	8	33	32	3	Good
4	I can solve the system of linear equations with Gauss Jordan elimination	1	5	9	8	23	1	10	27	32	3	Good
5	I can explain the meaning of matrix	1	3	8	11	23	1	6	24	44	3	Good
6	I can determine the operation result of two matrices	1	3	7	12	23	1	6	21	48	3	Good
7	I can explain the meaning of determinant	1	4	8	10	23	1	8	24	40	3	Good
8	I can determine the determinant of a matrix by using cofactor expansion	1	4	10	8	23	1	8	30	32	3	Good
9	I can determine the determinant of a matrix by using row reduction	1	4	9	9	23	1	8	27	36	3	Good
10	I can prove that a set is a vector space	1	5	9	8	23	1	10	27	32	3	Good
11	I can prove that a set is a subspace of a vector space	1	4	11	7	23	1	8	33	28	3	Good
12	I can show that some vectors are linear combinations of a vector	1	6	8	8	23	1	12	24	32	3	Good
13	I can show that a vector spans the set	1	5	10	7	23	1	10	30	28	3	Good
14	I can show a linearly independent or linearly dependent set	1	7	7	8	23	1	14	21	32	3	Good
15	I can show that a set is the basis and dimension of a subspace in a vector space	1	7	6	9	23	1	14	18	36	3	Good

The results showed that preservice teachers' responses on (1) the knowledge of elementary linear algebra material as well as the ability to (2) explain the meaning of linear equation system, (3) explain

Gauss Jordan Elimination method, (4) solve a system of linear equations with Gauss Jordan elimination, (5) explain the meaning of matrix, (6) determine operation result of two matrices, (7) explain the meaning of determinants, (8) determine determinant of a matrix using cofactor expansion, (9) determine determinant of a matrix using row reduction, (10) prove a set is a vector space, (11) prove that a set is a subspace of another set, (12) show that a set is a linear combination of other sets, (13) show that an element spans a set, (14) show a linearly independent or linearly dependent set, and (15) show that a set is the basis and dimension of a subspace in a vector space were all in the good category as indicated by an average score of 3 for all the indicators. This means the response of preservice teachers to the knowledge aspect is positive.

These results support the improvement observed in the learning outcomes of preservice teachers as presented in the previous analysis and this simply means they have good knowledge of elementary linear algebra material after the combined learning system was applied. This is associated with the fact that the learning materials placed on the e-learning platforms were very helpful to preservice teachers to understand the materials before they were discussed in the webinar classes. This shows the process of learning mathematics would not have been difficult during the pandemic had it been the materials were presented through e-learning platforms. This is in line with the findings of Das (2020) that mathematics education is usually easier when conducted through virtual classrooms as well as the recommendation of Noviani (2021) that e-learning design can be used to minimize the barriers to the achievement of learning objectives. The results of the responses to the attitudes aspect are presented in the following Table 5.

Table 5. Responses to the attitude aspects

No	Statements in the questionnaire	The number of preservice teachers' responses in each category (n)				Total of respondents	Analysis result					
		less (1)	enough (2)	good (3)	very good (4)		$n \times 1$	$n \times 2$	$n \times 3$	$n \times 4$	Average	Category
1	I always download teaching materials from the e-learning platform	1	0	5	17	23	1	0	15	68	4	Good
2	I always respond to discussion forums on the e-learning platform	1	5	7	10	23	1	10	21	40	3	Good
3	I always download tasks, work on them, and upload answers on the e-learning platform	1	1	5	16	23	1	2	15	64	4	Good
4	I always take webinar classes	1	0	5	17	23	1	0	15	68	4	Good
5	I actively ask questions and answer during webinar class	1	6	8	8	23	1	12	24	32	3	Good

The results showed that the habit to download teaching materials on the e-learning platform was in a good category as indicated by a score of 4 and the same was observed for the habit to download,

work, and upload answers, and take webinar classes. Meanwhile, the habit to respond to discussion forums on the e-learning platform as well as actively ask questions and answer during synchronous classes were found to be in a good category as indicated by the average score of 3. This simply shows that preservice teachers' response to the attitude aspect is positive.

The attitude of preservice teachers in synchronous and asynchronous learning conducted using e-learning was observed to be one of the positive factors that affected their knowledge of elementary linear algebra. They were enthusiastic about the online learning and active on both platforms used. The results were discovered to be in line with the findings of Wijaya (2020) that showed a good student learning attitude towards learning video because they felt it was effective in making them understand the concept being taught.

The results related to the responses of preservice teachers to the e-learning and webinar classes applications are also presented in the following Table 6.

Table 6. Responses to e-learning and webinar classes applications

No	Questions in the questionnaire	The number of preservice teachers' responses		Total of respondents	Analysis result	
		Yes	No		Yes	No
1	Do you have difficulty accessing the LMS (e-learning) class application?	9	14	23	39%	61%
2	Do you have difficulty accessing webinar class applications (Zoom, Google Meet, etc.)?	4	19	23	17%	83%
3	Is LMS (e-learning) class useful for you during the learning process?	23	0	23	100%	0%
4	Is the webinar class (Zoom, Google Meet, etc.) useful for you during the learning process?	23	0	23	100%	0%

Table 6 shows that 61% of preservice teachers had no difficulty in using the e-learning class application while 83% had no problems using webinar class applications and this means they have the appropriate skills to use these platforms. These findings were observed to be related to the previous results on the attitudes of respondents to the combined learning strategy. This shows they have had no difficulty in participating in e-learning and webinar classes and are ready to face the Industrial 4.0 period as suggested by Mairing, et.al (2021).

The results also showed that all preservice teachers agreed that e-learning and webinar classes were beneficial and this is supported by the feeling of enthusiasm and activeness expressed in using the combined learning method as indicated in the attitude analysis. This is in line with the findings of Amiti (2020) that appropriate combination of synchronous and asynchronous e-learning methods can assist teachers and students in having successful course and results despite the preference of students for both methods.

The results of the responses of preservice teachers to the frequency of accessing e-learning classes in a week are presented in Table 7.

Table 7. Responses to the frequency of accessing e-learning classes in a week

No	Questions in the questionnaire	The frequency of access in a week			Total of respondents	Analysis result		
		one time	two times	three times		one time	two times	three times
1	How many times do you access LMS (e-learning) classes in a week?	4	4	15	23	17%	17%	65%

Table 7 shows that 65% of preservice teachers accessed e-learning classes 3 times a week while 17% accessed 1 and 2 times a week. These results indicated that they were enthusiastic and active in using the synchronous and asynchronous e-learning platforms as indicated by the fact that more than 50% accessed it 3 times a week. This means they made good use of the facility to support their learning process due to its ability to provide everything needed to learn. This is in line with the findings of Xie, et.al (2018) that students preferred to use asynchronous learning because it can be easily accessed offline as well as its suitability for shy students. Raymond, et.al (2016) also recommended the use of innovative e-learning platforms in higher education institutions and promoted lecturers to use both synchronous and asynchronous learning in the form of e-learning platforms.

These findings showed that synchronous and asynchronous learning through e-learning can be combined as an alternative online learning method to teach mathematics during the Covid-19 pandemic. This is associated with several reasons which include the availability of teaching materials and assignments on the e-learning platform which is asynchronous learning and considered very helpful to preservice teachers in understanding the materials before the discussion during the webinar class which is synchronous learning. Asynchronous learning makes the learning process more effective because it provides opportunities to study materials, download tasks, and upload tasks as well as the ease with which both e-learning and webinar platforms can be accessed and used. Therefore, it is recommended that higher education institutions use innovative e-learning platforms while lecturers are promoted to use both synchronous and asynchronous learning methods (Raymond, et.al, 2016).

Teachers are considered professional in the millennial 4.0 when they have the ability to manage their classes through virtual learning activities. Siregar, et.al (2021) showed that preservice teachers already had quite a good perception of online learning while attending lectures during the Covid-19 pandemic. Their lecturers also have the ability to formulate teaching materials and assess assignments online in order to increase the learning opportunity for students.

Conclusion

The results showed that learning outcomes after synchronous and asynchronous learning was effective. This was indicated by the results of mid test and final test of elementary linear algebra

after it was taught through the combination of synchronous and asynchronous learning was significantly good. The questionnaires analysis showed that most of preservice teachers provided positive responses to this combined learning method as indicated by the knowledge and attitude aspects as well as the ease of access and usefulness of the e-learning and webinars platforms. It was also discovered that they often access the e-learning platform to study materials, download and do tasks, as well as upload answers.

This means the combination of synchronous and asynchronous learning activities is an alternative online learning method for lecturers to teach mathematics materials during the Covid-19 pandemic. It is recommended that further studies apply both learning methods through e-learning to critical thinking, creativity, communication, and collaboration (4Cs) considered to be very relevant and needed in this 4.0 era. There is also the need to access its effectiveness after the pandemic is over.

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